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The "Westminster" Series

TOWN GAS AND ITS USES

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TOWN GAS

AND ITS USES

FOR THE PRODUCTION OF LIGHT, HEAT, AND MOTIVE POWER

BY

WILLIAM HOSGOOD YOUNG WEBBER,

CIVIL ENGINEER,

STAFF INSTRUCTOR AND LECTURER OF THE GAS LIGHT AND COKE COMPANY, LONDON; SECRETARY OF THE ADVISORY COMMITTEE OF THE INSTITUTION OF GAS ENGINEERS FOR THE INTERNATIONAL GAS EXHIBITION, EARL'S COURT, 1904; AUTHOR OF "LIGHTING," "FACTORIES WITHOUT CHIMNEYS," "A SHORT ACCOUNT OF COAL GAS," ETC.

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PREFACE

This book is a summary of what I know, that appears to me to be likely to interest a generally well-informed but not technically instructed reader, about the manufacture and supply of Town Gas and its uses. There is no other work devoted to this aspect of the subject, which is so closely associated with the life and work of modern towns that " the country " has been defined as " the parts beyond the gas lamps."

There is reason for thinking that few of the large section of the public which has to do in one way or another with Gas, as consumers, or as owners of Gas property, have yet learnt to adequately appreciate the part which this great industry is competent to fulfil in the service of the community as a saver of domestic labour, a household comfort, an aid to manufactures and trade, a cure for the smoke evil, and a frugal utilization of our national coal supply. The statements made and the views expressed in the following pages respecting these and other matters, some

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of which may be debatable questions, are purely personal where no authority is cited, and are neither final judgments nor representative of aught beyond the fruits of my own experience and reflection.

The examples of apparatus illustrated, from drawings and photographs for the use of which I am indebted to various firms and others, are to be regarded as selected types of their kind, rather than as indicating any preference for the particular design or make thus signalized.

THE AUTHOR.

September, 1907.

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TOWN GAS AND ITS USES.

CHAPTER I.

THE NATURE AND PROPERTIES OF "TOWN GAS."

Definition of term "Town Gas"—Importance and volume of the gas industry—Its recent expansion—Physical properties of Gas—Its nature and legal description—Specimen analyses—The town gas of the future—Definition of illuminating power—The invention of the incandescent gas light—Effects of this invention—Economic and industrial bearings of the illuminating power standard of quality—Gas photometry—Meaning of candle power—The purity of gas—The fuel value of gas—Its flame-temperature—Gas pressure.

"Town Gas" is the name that has been given of late years to the familiar gaseous combustible and illuminant which is distributed by means of pipes laid under the streets of every considerable town and populous neighbourhood throughout the civilised world. Originally called "coal gas," or simply "gas," this commodity has everywhere been manufactured and distributed by identical methods, the composition also being uniform, ever since the industrial and commercial possibility of this enterprise was established by a London company, now styled The Gas Light and Coke Company, in the early years of the last century. The qualifying word "town," quite properly prefixed to the name of the manufacture in recent years, is in recognition of the circumstance that technical and

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economic considerations, operating with varying force, have brought about in different localities the admixture with the coal gas of a new preparation called technically "water gas," or "carburetted water gas." In some parts of the United States the latter product forms the whole of the supply. Even when so modified, however, the general character and useful properties of the commodity conform to the same type, which has stood its ground for a hundred years, and for which there is an ever-increasing demand, as its multifarious uses and adaptability become more fully recognised.

The growth of the town gas industry of the United Kingdom during recent years fully bears out the foregoing statement. Statistical returns, dated 1906, give the total number of active gas undertakings in the kingdom at 1,622, with an output of about 179,000,000,000 cubic feet per annum, and bearing 5,260,800 consumers, and 703,000 public street lamps on their books. The capital employed is about 120 million pounds sterling; all remunerative. Of the total number of consumers, nearly 2,000,000 are supplied by cash pre-payment, or "penny-in-the-slot" meters, a branch of the business that has been created within the last ten years. Almost as many householders cook by gas—an innovation scarce twenty years old. Whilst the tale of gas-heating appliances and gas engines in daily use cannot be set down, as no census of them exists, it is known to be very great, and growing fast. It is commonly estimated by gas engineers that already quite half of the consumption of gas in English towns is for household and trade purposes other than lighting.

The total gas consumption of the United Kingdom has more than doubled within the last twenty years; which fact, taken in conjunction with what has just been stated as to the contemporaneous creation of the fuel and power

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branches of the business, might without explanation suggest that the lighting branch has not grown in volume. Really, however, the increase of gas lighting has been large, although the volume of gas used for the purpose has considerably diminished in proportion to the amount of light obtained from it, owing to the vastly superior efficiency of the incandescent method of lighting now in general use over the lighting systems of twenty years ago. The difference is, roughly, as from ten or twenty to one, according to the systems compared: that is to say, for the same quantity of gas consumed, from tenfold to twenty-fold the amount of light is now easily obtainable, as compared with the effect of the kind of burners employed before modern invention had opened up this fruitful field.

The flourishing state of the town gas industry can only be accounted for by the public appreciation of the merits of its staple; and, generally speaking, of the system of the supply. For, in practical affairs, the deserts of all commodities and public services are appraised on various different grounds, which in effect combine to produce the net result of commercial success, or failure. Thus, the good properties of a particular article of consumption may be rendered nugatory by the existence of certain objections to its use; or by the occurrence of trouble and difficulties in the way of procuring it. In the case of town gas, its success in holding the market against all rivals of the same order of utility is due, first, to its possession of certain valuable and unique physical properties, namely:—

(1) It is the sole permanent gas suitable for consumption, in or out of doors, either as an illuminant, or a smokeless fuel of high or low intensity, or as a source of motive power: all from the same supply system.

(2) It is susceptible of perfect sub-division, without loss of efficiency, for use in every required application for

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lighting, or the production of heat or power. The cost to the consumer is always in direct proportion to the quantity consumed.

(3) As an illuminant it is equally serviceable as a "watch light," burning all the year round with the same reliable glimmer, up to the most powerful light, of 1,000 or 1,500-candle power, suitable for public street, promenade, railway station, or workshop lighting. It is appreciated on the wharfside as well as in the boudoir.

(4) It is a readily available fuel, cleanly and inoffensive, to be obtained by the turning of a tap, which will grill a chop, boil a kettle, heat a flat-iron; or melt a crucible charged with platinum. There is no metallurgical, or smith's work for which its heat is not adequate; no household warming for which it is not suitable. As a means of domestic cooking and heating it is incidentally a practical cure for the smoke nuisance of towns.

(5) As a source of motive power it is cheaper, handier than, and free from the drawbacks of steam engines in populous places. For whatever purpose it is used, it leaves no residue calling for removal; reduces labour and supervision to the minimum; has no "making ready," or "stand by" losses; is always available on the instant; involves no extra cost for insurance; is safe in manipulation.

Physical Characters.—Town gas, as supplied in London and suburbs and the South of England generally, is chiefly made by distillation from the sea-borne coal of the North of England, with some local additions in a minor proportion of water gas, or carburetted water gas. This class of town gas, it may be stated, is the normal supply, not only of the British Metropolitan region, but also of all places whose natural (in the economic sense) gas coal supply is of the same origin and carriage. It is legally classified as being of from 14 to 16 candle-power; and usually has a calorific

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power of about 540 British Thermal Units, net, per cubic foot. Its proximate composition varies slightly with the proportion of water gas it contains. It has about the following composition:—

Hydrogen	43·38	combustibles and illuminants.
Marsh gas	29·29	
Light-yielding hydrocarbons	4·64	
Carbon monoxide	15·62	
Carbon dioxide	1·50	inert gases.
Oxygen	0·26	
Nitrogen	5·31	
	100·00	

It will be noticed that of the above product, all but about 7 per cent. is combustible. This sample requires about 5¼ times its own volume of air for its complete combustion, and is two-thirds coal gas and one-third carburetted water gas.

A sample of wholly coal gas, of 15½-candle power, made from Newcastle coal, shows the following composition:—

Hydrogen	48·49	combustibles and illuminants.
Marsh gas	35·90	
Light-yielding hydrocarbons	3·83	
Carbon monoxide	6·61	
Carbon dioxide	0·12	inert gases.
Oxygen	nil	
Nitrogen	5·05	
	100·00	

This gas requires about 5½ times its volume of air for complete combustion.

In the Midlands, gas is made from various local coals,

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usually of a somewhat richer character than the Newcastle shipments. Birmingham gas, for example, has been returned as of the following composition:—

Hydrogen	43·40	combustibles and illuminants.
Marsh gas	33·67	
Light-yielding hydrocarbons .	4·48	
Carbon monoxide	9·46	
Carbon dioxide	0·16	inert gases.
Oxygen	0·13	
Nitrogen	8·70	
	100·00	

Illuminating power, 17-candles. Calorific power, net, 553 B.T.U. Air required for complete combustion, 5·4 vols. to 1 vol. of gas.

The flame temperature of any of these town gas supplies, burning in air, is higher than the melting point of platinum, and is probably in the neighbourhood of 1800°C. to 2000°C.

In Scotland, the richness of the local cannel coals has rendered possible a correspondingly high illuminating power of the gas supply, running up to 27 and even 30-candles; but since so large a proportion of the supply has come, as elsewhere, to be used for purposes other than direct lighting with the luminous flame, a movement has started there also for reducing the candle power to the usual English standard, which would considerably lower the price.

This movement has already made great headway in England, and undoubtedly, if economic and technical considerations had free play, untrammelled by obsolete Parliamentary requirements, and the reactionary tendencies of a few municipal authorities, before many years had passed

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there would be little else sold besides 13 or 14-candle gas averaging about 525 B.Th.U., net, wherever the coal to make it from could be had cheap.

The reasons for this conclusion are manifold, and lie on the surface of the present conditions affecting the gas industry and the public it serves. Gas of the character in question, containing under 10 per cent. of inert constituents, is found by large English and European experience to be quite suitable for all the purposes of a town supply. Under the conditions formerly prevailing, when gas was sold exclusively for lighting by its luminous flame, the criterion of its value to the consumer was its illuminating power. Therefore, wherever the supply was under statutory control, the undertakers were compelled under penalties to maintain the covenanted illuminating power, which was usually fixed at the highest figure corresponding to the possibilities of good working and careful management of the most suitable raw material available.

This standard also referred to a particular test burner, and a fixed rate of burning of the gas. The burner had to be such as would show the gas to the best advantage, while being suitable for use by the consumer. That is to say, whilst being the best appliance of the kind for developing the illuminating power of gas, the test burner was not to be a philosophical instrument, but an ordinary trade article, such as anyone might buy and use. The rate at which the gas was burnt for testing was uniformly 5 cubic feet per hour, this being a common practice; but the choice of the test burner was left open to every undertaking by agreement with the local authority. It usually went by the quality of the supply. In London, and for gas made from common North of England coal, which ran from 14 to 16 candles, the test burner was, and is, always of the Argand type—a ring of holes, with a chimney adjusted to draw in

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the proper quantity of air to completely burn the gas. If the provision of air in such a burner is insufficient to burn the gas at the prescribed rate, the flame smokes and tails above the top of the chimney. A larger chimney is then taken. If there is an excess of air, the gas is burnt too quickly, with too short a flame, to develop its full illuminating power.

In the case of gases of higher illuminating power, say, 20 candles (at which the expensive quality known as cannel gas was understood to begin), this solicitude for proper adjustment of the air to the burner ceases to be necessary. Therefore, the test burner for such gases was, and is where they are retained, a flat-flame burner, such as the majority of consumers used everywhere. For the quality of gas represented by an illuminating power of 20 candles, or thereabouts, the use of either an Argand or a flat-flame burner for testing purposes is a matter of indifference to the result in candle power of the gas, burning at the rate of 5 cubic feet an hour. With the lower-grade gases already described, the use of open flat-flame burners always results in a loss of illuminating power by over-aëration. In the older Acts of Parliament regulating gas undertakings in which the highest possible illuminating power was imposed for common coal gas, such requirement was frequently found excessive, having regard to the character of the available coal supply. It consequently entailed on the manufacturers the expensive and illusory expedient of "enriching" their output, as it was mistakenly termed, by the addition of such foreign hydrocarbons as petroleum spirit; which merely satisfied the illuminating power standard without contributing to the intrinsic value of the supply. In those days, the calorific power, or fuel value, of town gas was not considered at all.

It was not until the Welsbach invention of gas lighting

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by the heating to incandescence of a foreign substance in the bunsen, or non-luminous flame of gas mixed with air, had become an assured success, that the supremacy of luminous flame illuminating power was brought into question. This was in the year 1900. In the Parliamentary session of that year the South Metropolitan Gas Company, of London, promoted a Bill with the object of repealing the statutory obligation which, for upwards of thirty years, had lain upon them, together with the two other London gas companies, to maintain their common town gas at the standard illuminating power of 16 candles at the testing stations in the district of supply. The company proposed to reduce the standard to 14 candles, offering to forego any dividend out of the increased profits that might be realised by working to the lower standard. Their case was that not only might the public be reasonably expected to get cheaper gas by this arrangement, but also that for every purpose of the consumer the new and lower-priced gas would prove as good as the old.

This case was sustained by evidence establishing the facts: (*a*) that with the incandescent method of lighting, the gas was merely burnt as a fuel, just as for the purposes of cooking, heating, and the generation of motive power; (*b*) that luminous flame burners were fast disappearing before the superior brightness and cheapness of incandescent gas light; (*c*) that such luminous burners as were commonly used by the public were bad, and failed to secure anything like a proper share of benefit from the expensively high standard of illuminating power imposed upon the Company. Recognising the circumstance that some time must elapse before the general adoption of incandescent lighting could be brought about, and also that there might be expected to remain a small proportion of self-luminous burners in use for special reasons, the Company offered to

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supply their consumers gratis, during the transition period, with a better kind of flat-flame burner, which should yield more light from 14-candle gas than the generality of consumers' burners had given from the 16-candle gas.

The Company carried their point, and the example has been followed far and wide; although there are still some districts where the ill-advised policy of the local authorities in opposing the relaxation of the illuminating power standard, except on prohibitive terms, debars the public from being supplied with the cheaper gas to which this administrative step is the necessary preliminary.

The question of what is the best quality of town gas for any locality is merely one of value for money. In order to arrive at a satisfactory answer to it, the use in this connection of such prejudicial expressions as "rich" or "poor" had better be eschewed. The disestablishment, albeit partial, of the rule of 16-candle gas for London—meaning 16½ or 16¾ candles at the works, to provide against accidents—immediately relieved the pressure upon the gas coal market, and threw open enormous contracts which previously were treated as the preserves of the fortunate proprietors of the limited list of higher-grade coals capable of yielding gas of this class. The same result followed in respect of the mineral oils necessary for the manufacture of carburetted water gas. By the operation of the economic law of equivalent values, the price of best gas coals had ruled that of gas oils; so that the manufacturer of a grade of gas requiring select raw materials was pinched on both sides. This state of things fell away with the legalisation of the supply of 14-candle gas by some of the big undertakings; because practically any gas coal raised in the United Kingdom in large quantities will yield gas of this grade. It has quite naturally followed from

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this circumstance, that the manufacture of 16 or 17-candle gas is continued, where the cost of the superior raw material required to produce it has not risen out of proportion to the selling price of such higher grade gas.

It must be understood, as the key of the situation, that there is no economic or technical reason against the maintenance, for the time being, of the photometric test for town gas, when carried out in a reasonable spirit, for the protection of the consumer, according to just and fair methods. Although this expression of the quality of town gas has ceased to possess any other than a strictly conventional meaning, it nevertheless constitutes incidentally a real safeguard against the supply of diluted or adulterated gas. Before proceeding further, therefore, with the consideration of the useful properties of town gas, it will be expedient to explain the significance of this rule of classifying town gas, how the fact is determined, and what it implies.

Gas Photometry.—It has already been explained that town gas is valued by its "candle power"; meaning the equivalent brightness of its luminous flame, expressed in terms of the number of candles whose combined light is calculated to amount to that given by the test burner when consuming the gas at the prescribed rate, which is usually 5 cubic feet per hour. The candles in question are made of spermaceti, with a small admixture of beeswax to "break the grain," and of the commercial size of six to the pound. When burning at the rate of 120 grains per hour, the candle light is standard. There is no other standard of light known to English law. Every artificial light used in the United Kingdom or Greater Britain, or in the United States of America, is rated in terms of this standard candle. [The French standard of light is that given by the "Carcel" colza-oil lamp, which

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is not quite equal to the light of 10 English candles; although this is the equivalent commonly taken for the purpose of comparison, to avoid fractions. The German standard is the "Hefner" light, of a small chimneyless lamp, burning amylacetate, equal to about seven-eighths (·875) of an English candle.]

In photometrical experiments actual candles are now seldom used, a more convenient substitute having been sanctioned in which the equivalent luminosity of 10 candles is produced by a flame of the vapour of a special grade of petroleum spirit called "pentane" and air, burnt by means of a lamp invented by Mr. A. Vernon Harcourt.

The system of testing town gas practised in the United Kingdom can be best described by giving the particulars of the London practice, with the reservation that the details are not quite the same throughout the provinces. The direction of the statutory examination of the whole of the gas supplied in London by the three Metropolitan undertakings—The Gas Light and Coke, the South Metropolitan, and the Commercial Companies—is entrusted to a board of three "competent and impartial persons," the present triumvirate being Professors A. Vernon Harcourt, C. V. Boys, and J. S. Haldane, who are styled the "Gas Referees." It is their duty to issue yearly, or oftener if necessary, precise instructions for the testing of the gas at the metropolitan stations, 23 in number, which are so situated as to sample the output of the various gasworks. Three testings for illuminating power are made daily at every station, at intervals of not less than an hour. The average of these tests is taken to represent the illuminating power of the supply on that day; but if one test shows a deficiency of not exceeding one candle below what it ought to be, the average of that and the days before and after is deemed to represent the illuminating power for the day.

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The photometrical instrument used in the official London testing places is known as the "table photometer," which is simply the name of a certain disposition of parts requisite for the facile and accurate comparison of the lights of the gas burning in the test burner at the exact rate of 5 cubic feet per hour, and of the pentane lamp, together with the various regulating and measuring instruments necessary to ensure the utmost precision in the operation of making the test. The principle of the operation is the simple "law of inverse squares" applying to all forms of radiant energy, which will be discussed later in connection with lighting. This is, that "the intensity of the radiation varies inversely with the square of the distance." The human eye can only judge of the equality of illuminations, say, thrown side by side upon a field of vision susceptible of being equally lighted by two sources. It is necessary, therefore, if the quantity of light emanating from a source of unknown intensity is to be measured by being made equal on a lighted field, or screen, to that received by a contiguous part of the screen from another source of known intensity, that the relative distances of the two sources, after equality has been established by moving one of them nearer to or farther away from the screen, should be taken. It is the purpose of photometers to facilitate and exhibit the result of this balancing operation with the least chance of error; and the arrangement shown (Fig. 1) contains in a simple form the essentials for gas testing by the approved methods.

The test burner is known as "The Metropolitan Argand Burner, No. 2." It was invented by Mr. Charles Carpenter with a view to its use for all grades of town gas lying between 13-candle and 19-candle power; that is, for all gas capable of being properly burnt by a chimney burner of the Argand type, at the uniform rate of 5 cubic feet per

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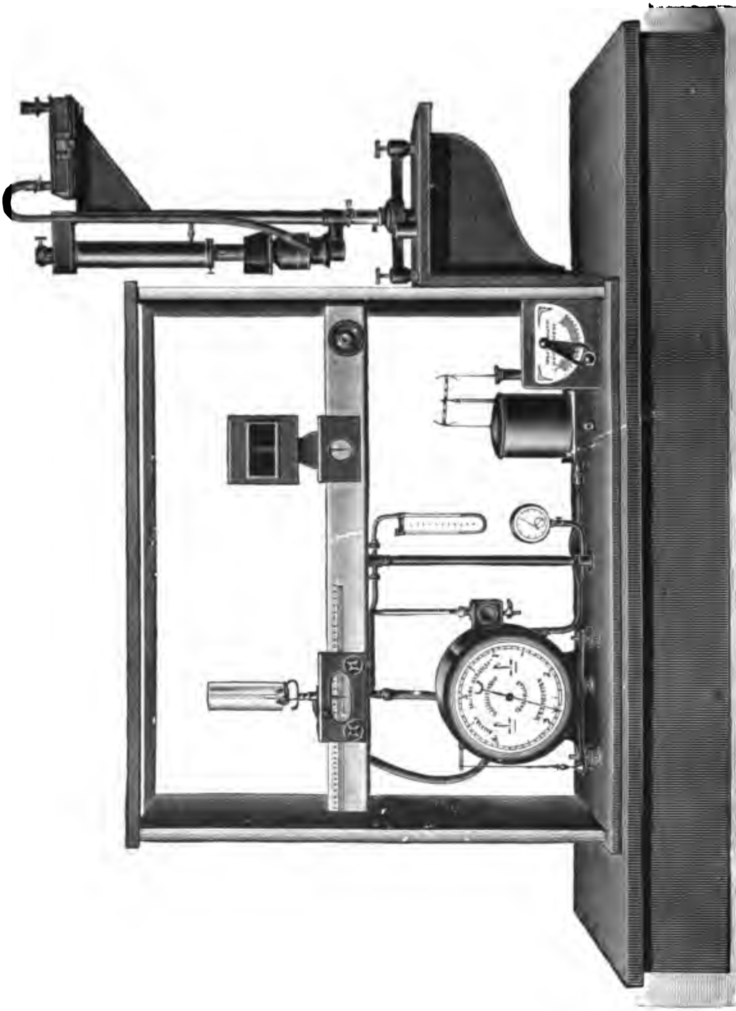

FIG. 1.—Gas Photometer, Works Model. The apparatus to the right of the illustration is the Harcourt 10-candle pentane-air-gas standard of light. Mounted on the graduated bar is the test burner, and the box containing the Bunsen photometric screen of greased paper, with an ungreased central spot, which is viewed from the front, and the test burner moved to and fro until the observer cannot distinguish the opaque spot in the field. This constitutes the condition of equal illumination of both sides of the screen. Beneath are the gas meter, gas pressure gauge, minute clock, gas governor for regulating the pressure, and a graduated cock on the gas supply pipe.

hour. It is the first, and, so far, the sole burner of this universal applicability, which is secured by making mechanical

provision for the adjustment of the air supply to the flame to the quantity proportional to its physical requirements in this respect (Fig. 2). It has already been explained that this quantity varies with the composition of the gas; and the Carpenter burner simply enables the observer of the burning of a sample of gas, of unknown composition, to adjust the supply of air to maintain the regulation 5-cubic feet flame at its highest luminosity, which is when it is just short of smoking, in still air.

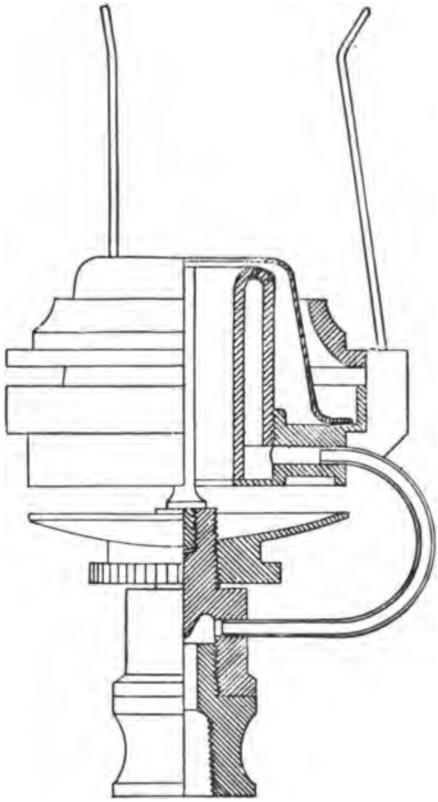

FIG. 2.—Carpenter's London Argand Burner No. 2 (actual size).

The working standard of light, the Harcourt 10-candle pentane lamp, has already been mentioned. The meter for measuring the gas, the pressure regulator, and the other accessories of the photometer room do not call for detailed description. Care is taken at the official testing stations to regulate the temperature of the room, and ensure a fair sampling

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of the gas passing in the street main, because the testing is a legal procedure, and its results are evidence for action against the company supplying the gas, in the event of default.

Such is the manner of testing town gas for illuminating power, and the result thus arrived at represents the conventional rating of the supply in terms of candle power. This rating of town gas, as of 14 or 16-candle power, or more, has ceased to correspond with the real lighting power of the gas in the hands of the consumer; because no one who wished to obtain the best value for money spent in gas for lighting would dream of burning it in this way. In practice, the consumer has no use for a burner of the type employed in determining the parliamentary illuminating power of the gas he buys. Instead of the Argand luminous flame, burning gas at the exact rate of 5 cubic feet per hour, and showing a light therefrom of from 14 to 16-candle power, the public prefer incandescent burners, upright or inverted, which, for a consumption of from 3½ to 4 cubic feet of gas per hour, will give a light of 70 to 80-candle power. And if for draughty corridors, outbuildings, lavatories, and similar situations, where all that is wanted is to "show a light," the simpler flat flame burner is still used on account of its serviceability, its consumption is seldom more than 3 to 4 cubic feet an hour, and there is no question of illuminating power in the case.

Yet notwithstanding this lack of correspondence between the legal denomination of town gas by its candle power under statutory test conditions and the luminous effect realised by the consumer, the former remains, as already pointed out, a real safeguard for the consumer, for which there is no known substitute of such easy applicability. The chief objection to its detention as a penalty test, is the opening it provides for vexatious prosecutions of gas

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companies for insignificant, temporary, or local deficiencies of illuminating power. Assuming the acceptability for all purposes of the grade of town gas already specified, showing with the most suitable test burner, as adopted by the London Gas Referees, the normal illuminating power of 14 or 16 candles with the 5-cubic feet flame; together with a minimum calorific power of 500 British thermal units net, and containing not more than 10 per cent. of inert gases—the question arises, how shall the consumer be protected, and assured of always getting gas which is of the nature and quality bargained for?

The best test available is that for illuminating power, because it shows unmistakably the presence in the gas of any excess of inert diluent, which very quickly destroys the luminosity of the flame. One per cent. of carbonic acid reduces the illuminating power by 4 per cent., and the effect of these inert gases rises out of all arithmetical proportion to their quantity. Thus, while the addition of 1 per cent. of air to purified gas diminishes its illuminating power by about 6 per cent., 4 per cent. of added air would reduce the illuminating power 25 per cent. Therefore, it is evident from these facts, which are amongst the commonplace data of the town gas industry, that regular testing for illuminating power reasonably conducted, not in the spirit of a "police trap," is quite competent to prevent adulteration of the product with incombustibles foreign to its true character.

The Purity of Town Gas.—It is a leading characteristic of town gas that, being manufactured with a view to indoor consumption, it is carefully purified from the injurious and offensive matters which are always given off from burnt or gasified coal. The most objectionable of these is sulphuretted hydrogen, which has a very offensive odour, also blackens silver and bright metals generally, and burns to

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an acid gas which is actively corrosive. There are also tarry vapours and ammoniacal liquor, all of which are found associated with free carbon or soot in coal smoke. Town fogs are chiefly composed of the noxious products of the conversion of coal into crude gas, which are carefully removed from the gas supply of towns. This purification is expensive, and the consideration must be set off against the alleged cheapness of some other unpurified gases of limited utility as fuel, or a source of motive power, which are sometimes proposed in competition with it.

It is forbidden by law that town gas should contain the slightest trace of sulphuretted hydrogen impurity. The tests for this are extremely exacting, and are maintained in constant action. W. J. Dibdin has found that the sensitiveness of the legal test for sulphuretted hydrogen in town gas is such that the presence of 0·030 grain in 100 cubic feet, the weight of which is 25,000 grains, can be detected. There is another kind of sulphur impurity always present in all coal or oil gas, which it has hitherto been found impossible to wholly remove. This is technically classified as "the sulphur compounds," and comprises sulphur combined with carbon, and sulphur in combination with organic matters which have never been chemically identified. The proportion, therefore, in which the sulphur compounds occur in gas made from coal or oil depends mainly upon the character in this respect of the raw material. The total quantity of sulphur in these forms which may remain in town gas rarely exceeds 40 or 50 grains in 100 cubic feet. The hygienic aspect of this sulphur in town gas will be discussed in a later chapter. For the present, it may suffice to point out that the presence of what is chemically designated sulphurous impurity in town gas has the important redeeming advantage of imparting to it its well-known odour, which is so indispensable as an indication

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of leakage, that if it were not natural to the gas something of the same character would have to be artificially added to any illuminating or fuel gas admitted inside inhabited buildings.

THE FUEL VALUE OF TOWN GAS.—The fuel value, or, more scientifically speaking, the "calorific power" of town gas, is a quality of the service which has only become appreciated during the last 20 years. At one time, when gas was solely used for lighting, its heat was even regarded as an objection. The leading text-book of the industry, in an edition dated 1872, makes no mention of the use of gas for any purpose other than lighting; and so lately as 1882, when cooking and heating by town gas had become so firmly established that it was possible to hold an exhibition of gas stoves at the Crystal Palace, there was no instrument available for measuring the heating power of gas. Since then, attention has been given to this subject, and it has become habitual with gas engineers to speak of town gas in terms of its calorific power, as already mentioned. It will be convenient to explain what is meant by this terminology.

The unit of heat measurement employed in this book, which is written for English readers, is the British Thermal Unit (B.Th.U.); which is also that commonly used by English gas engineers. It is the quantity of heat necessary to raise the temperature of one pound of water 1° F., at or near 39° F., the temperature of maximum density of water. (In practice, no correction is usually made for any difference between the ordinary temperature of water and that of its maximum density). In the science of chemistry, the metric system of weights and measures has been adopted, and accordingly some experimenters state results in the metric thermal unit, called in French the *calorie*, which is the quantity of heat corresponding to the rise or fall of temperature of a kilogramme of water 1° C. This

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calorie is equal to 3·968 British Thermal Units. Conversely, the B.Th.U. = 0·252 calorie. Within 3 per cent., therefore, the French and English industrial units of heat are to each other as 4 to 1.

Calorimeter determinations of the heating power of town gas are not yet legalised with a view to forfeitures; but they are now made regularly at the London testing stations for information only. The instrument officially used for the purpose is the design of Professor Boys, and differs from others commonly employed by gas engineers unofficially, in being readily taken to pieces for examination. In making a test, a measured quantity of gas is burnt so as to impart as much of its heat as the mechanical disposition of the apparatus permits to a flowing stream of water; the water of condensation from the gas itself being also collected separately. The total heating effect of the gas, as measured in the first stage of the operation, is called its "gross calorific power." After the proportion of heat represented by the condensation of the water of combustion is deducted from this total (this amount of heat not being regarded as performing any useful work) the result is called the "net calorific power" of the gas; which is the figure in British Thermal Units per cubic foot of gas that engineers take for its fuel value. The difference between the two figures is governed by the proportion of hydrogen, which burns with the oxygen of the air to form water, in the mixture of gases. Hydrogen alone shows a calorific power per cubic foot of 344 B.Th.U. gross; and 294 B.Th.U. net—the latter being therefore 14½ per cent. off the larger figure. At the opposite extreme, carbon monoxide shows the same calorific power, gross and net. All the hydrocarbons, therefore, which with these two components make up the combustibles of town gas, fall in somewhere between these calorific data, the difference being usually taken

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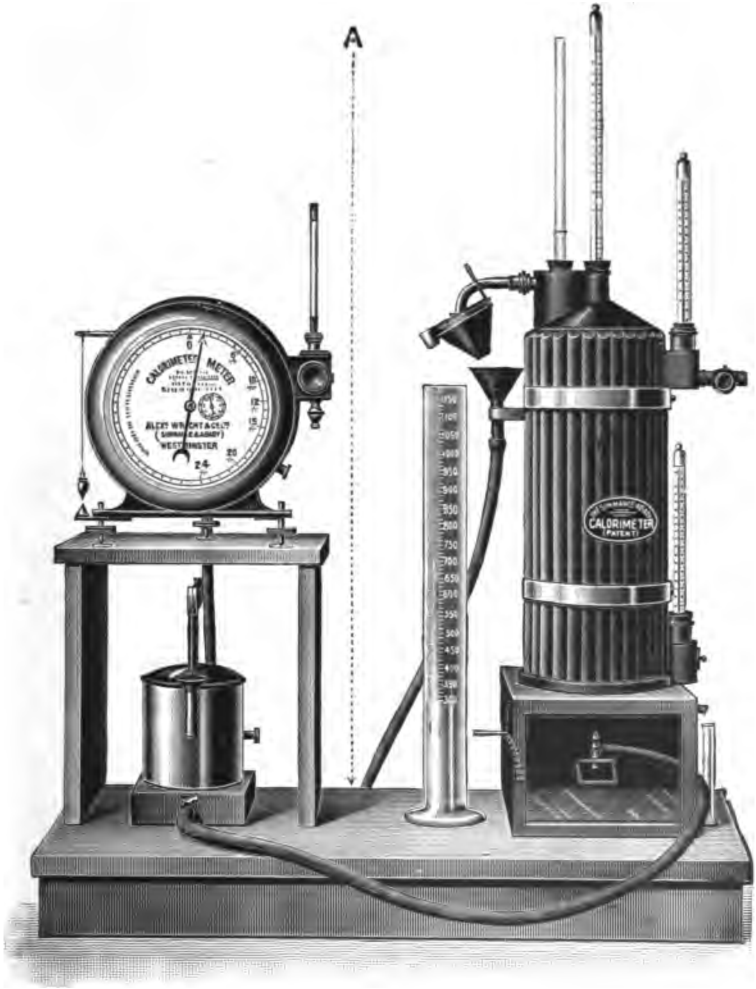

FIG. 3.—Simmance-Abady Calorimeter for Gas The calorimeter itself is shown on the right of the dotted line A, the articles on the left being the accessory meter, and gas governor. The calorimetric apparatus comprises the gas burner, shown at the bottom, and the jacketed vessel in which the flowing water is caused to absorb the heat of the burning gas. Thermometers for indicating the temperature of the water before and after heating, and also of the products of combustion, are shown in position; and also the graduated measures for the heated water, and for the water of combustion.

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roundly at 10 per cent. Whenever calorific power is in question, therefore, as often happens in comparing fuel gases of different kinds with one another, it is necessary to be sure which value is meant.

Doubtless, in the course of time, when the practice of gas calorimetry shall have become as well established as that of photometry, a calorimetric standard for town gas will be legalised by agreement in many places. Calorific power has the advantage of being very uniform, and there should be no difficulty in conforming to a minimum, say of 500 B.Th.U. net, with a reasonable standard of illuminating power to match. These tests should be carried out by the county council as in London, independently of the local authority, and irrespective of the supply being in public or private hands.

The maintenance of a uniform calorific power, according to a known standard, would be very helpful both to the consumer of town gas for fuel purposes (fast overpowering any other use for it) and also to the makers of gas heating appliances and gas engines, who would be better able to standardise their manufactures.

Flame Temperature.—This property of a fuel gas is distinct from its calorific power. The term means in practice the actually realisable temperature by the bunsen, or non-luminous atmospheric flame. This kind of burner is commonly employed for heating and boiling, chiefly because of its cleanliness, as it does not deposit soot on the vessels; but for the finer requirements of incandescent lighting burners, and also for heavy metallurgical work, it is susceptible of considerable development in the sense of intensifying the flame temperature. Thus, by thoroughly mixing the air and gas before combustion, and increasing the proportion of the former drawn in by the injector action of the gas jet to the explosion point (that is to say, when

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the mixture contains enough air to completely burn the gas) the flame is concentrated into the smallest possible space, is "solid" throughout, and is most intensely hot. Platinum readily melts on the surface of an incandescent Welsbach mantle. With air forced in under pressure, a degree of temperature is attainable with town gas which only the most refractory earths will withstand. The industrial advantages of having this intense heating power at command are obvious. With the exception of acetylene, which is more limited as to scale, and "water gas," which is never distributed, town gas alone possesses this high flame temperature. It is therefore largely used in dockyards, arsenals, and engineering works for welding, fusing, and tempering metals. For such operations as shrinking on gun rings or heavy iron tires, the saving of time alone, as compared with slower firing, pays for the town gas.

Pressure.—Consumers of town gas should satisfy themselves (through the gasworks officials) that the pressure at the points of consumption is sufficient to enable them to use their gas supply to advantage. It is often remarked that, for ordinary consumers, there is no such thing as "bad gas," if the pressure is right. This is so far true, that without exception consumers' complaints of bad gas, when they do not relate to defective appliances, always proceed from insufficient pressure. This is a matter which invites co-operation between the supplier and the consumer. The former has to incessantly watch the effects upon his street mains of the increasing demands of the various districts of supply, and also those of rapid changes of atmospheric temperature in provoking sudden deposits of naphthalene, blocking the pipes. This troublesome substance is not an impurity of town gas, to which, on the contrary, it adds illuminating power. But it is apt to

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condense in the main pipes, and consumers' service pipes, as it were, capriciously; and being in its solid state an extremely light, flaky substance, a little of it does great mischief in blocking the gas-ways. It can be removed if notice of failure of the supply is given in the proper quarter.

Consumers not infrequently lay up disappointment for themselves by adding to their gas apparatus without thought of how they may be over-taxing the capacity of service pipe, meter, or interior piping. Attention to the pressure will reveal all such mistakes, and ensure satisfaction.

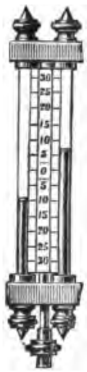

FIG. 4.—Gas pressure gauge, indicating a pressure reading of "17 tenths."

Note on the Measurement of Gas Pressure.—The pressure of gas in the pipes which distribute it for consumption is measured in terms of the height of a column of water which counterbalances it, expressed in inches and tenths of an inch—usually in "tenths." This is really the "head" of the confined gas, above the atmospheric pressure, which causes it to flow through the pipes and escape from any orifice in the connections. Gas pressures in the distributing system are kept as low as will suffice for the purpose of supplying the quantity of gas required, because this is all that is wanted. Gas pressure is never employed to do any work as such, like steam pressure on the piston of an engine, but only as the agency for transmitting and delivering the gas to the points of consumption. Gas pressures formerly rarely exceeded 10-tenths, because the luminous flame burners of the ante-Welsbach period were low pressure appliances, working best at pressures of

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5-tenths to 8-tenths. Incandescent lighting burners, atmospheric heating burners for gas fires and cooking apparatus, &c., require a supply at 15-tenths. Consumers would be well-advised to ascertain from the gas company the maximum pressure they may expect; and where this exceeds 20-tenths "regulators" should be used, in order to prevent waste of gas.

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CHAPTER II.

THE HISTORY AND MANUFACTURE OF TOWN GAS.

Origins of the Town Gas Industry—Early struggles—Samuel Clegg, the first gas engineer—His endeavours and inventions—Introduction of the sale of gas by measure—The era of competition in gas supply—Its collapse and the consequences—How gas is manufactured—The carbonisation of coal—Side-lights from the coke manufacture—Gas retorts—Retort working machines—Possible improvements in gas manufacture—Horizontal *versus* vertical retorts—Products of carbonisation—Composition of crude gas—Treatment of gas in the works—Economy of the gasholder—Influences governing the prime cost of gas—"Unaccounted for" gas—Nature and manufacture of carburetted water gas—"Blue" water gas—"Fuel" gas—Superior advantages of town gas—"Producer," "Dowson," and "Suction" producer gases—"Mond" gas—The question of purity.

THE manufacture and supply of town gas, as a public service undertaking, dates from the incorporation by Act of Parliament, in 1810, of "The London and Westminster Chartered Gas Light and Coke Company." The practicability of the manufacture of illuminating gas by distillation from bituminous coal, and also of its application to the lighting of buildings and streets, had previously been established by the success of private plants at a few Birmingham factories. The creation of a public gas supply undertaking, however, was a different matter, involving the solution of innumerable problems of administration and technique, for which there was no precedent. The idea of pipe distribution of inflammable gas was met with violent opposition on grounds whose nature can be readily

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surmised. What was recognised as the scientific authority of the period ridiculed the scheme. People of influence, including the architect to the Houses of Parliament, could not understand that the gas pipes were not full of the flame that burnt at the tips. The fire insurance companies opposed gas lighting. The Royal Society advised the Government to compel the company to restrict the capacity of their gasholders to not exceeding 6,000 cubic feet, and enclose them in strong brick buildings. The public street lamplighters struck against the novel light, although it greatly reduced their labour. The parish authorities would not allow lamp posts to be placed in the streets; and a political agitation was organised for the defence of the whale fishery, which was thought to be jeopardised, together with "the unequalled nursery of seamen" which it represented, by the new way of procuring artificial light.

These external discouragements were as nothing to the internal difficulties of the adventurers. The Company started with great expectations; but necessarily without experience of the class of business they undertook, and of the nature of the manufacture in which they engaged. The promoter of the enterprise and his associates proved wholly incompetent to manage it; so that after three years of heart-breaking struggle against ignorance within and obstacles without, the pioneer gas company was on the verge of failure when it found its saviour in Mr. S. Clegg, a trained engineer who had had some experience in lighting private establishments with gas. It was Mr. Clegg, more than any other individual, who created the industry of town gas supply. He fought the Royal Society, the vestries, and the lamplighters. When the great Humphry Davy asked sneeringly whether it was intended to take the dome of St. Paul's for a gasholder, Clegg replied that he hoped to live to see the day when they would not be smaller. This

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hope was more than realised; for the diameter of the dome of St. Paul's is 145 feet, and gasholders of 200 feet diameter had been constructed before the death of the speaker in 1861. When the lamplighters struck work, Mr. Clegg shouldered a ladder and lit the gas lamps on Westminster Bridge. To satisfy the fire insurance companies, Mr. Clegg invented a self-closing burner, with thermostatic action, which shut off the gas whenever the flame became accidentally extinguished (as by temporary failure of supply) without the tap being turned off.

Everything needed by the company for the purposes of their undertaking had to be designed specially; and few manufacturers or merchants could be prevailed upon to accept orders for goods of the use of which they were ignorant, from a concern of whose future they were profoundly sceptical. Metal piping, to mention one example of manufactures which the gas industry had to evoke, was not obtainable; and the gas company had to make shift with old musket barrels screwed together. Mains were even made of stone. What have come to be looked upon as the most obvious elementary safeguards in the manufacture and after treatment of the gas had to be felt for through the rough discipline of explosions and fires; of course occurring where least expected. Thus, although the company's gasholders did not explode, a purifier did as early as 1813, immediately after Mr. Clegg took charge of the works, breaking several windows, and unfortunately severely injuring the engineer. He, however, found a means of preventing a repetition of the accident; and went on his pioneering way undaunted. The following year, on the occasion of the celebration of the Peace of Amiens, Mr. Clegg dazzled the town by the great novelty of gas illuminations, the most important of which, unhappily for the Company, was destroyed by the meddling of Sir William Congreve, who

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insisted upon letting off rockets from the framework. The next year, however, the Company secured a triumph which did much to set gas upon its feet, in the lighting of the City Guildhall.

Still, the struggles of the gas company continued to tax

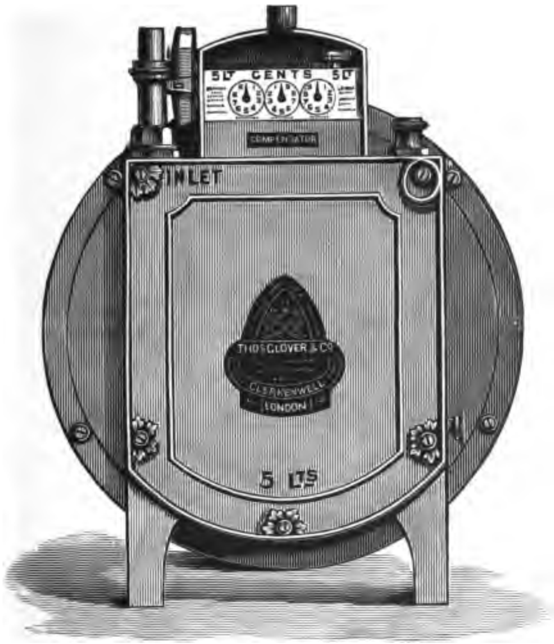

Fig. 5.—Wet meter in cast-iron case.

the powers of the cleverest brain, and to put an incessant strain upon the toughest nerves, such as Samuel Clegg surely possessed in a pre-eminent degree. All the adventurers' capital being spent, and borrowing being impossible, every penny of revenue that came in was wanted for alterations, repairs, and extensions. The supply to consumers was not measured, for there were no meters ; but the gas lights

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were rented at so much a year, or bargained for upon estimated consumption, a fruitful source of disputes and delayed payments. Of course, there were no dividends. Meanwhile, Clegg plodded on; training his workmen; arranging with enterprising people to manufacture the fittings without which gas could not be laid on to consumers'

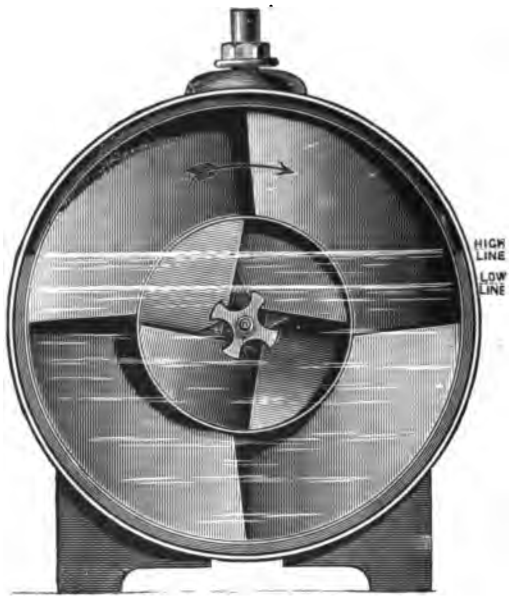

FIG. 5A.—Cross-section of measuring drum.

premises; organising the operations of the Company; meeting and circumventing obstacles and disagreeables innumerable; and in his leisure time lighting with gas Bristol, Birmingham, Chester, Kidderminster, and Worcester. Others who had picked up some of his art extended the benefit of town gas throughout the United Kingdom.

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It is quite English that this quiet, strong man, who was instrumental in founding one of the great national industries; who was to gas what George Stephenson was to steam railways, perhaps more, received no titular distinction of any kind during his laborious and fruitful life, and died in modest retirement at Hampstead, unknown beyond the circle of his family and professional associates. The latter, however, were then mostly of another generation, as Mr. Clegg outlived his own; while the sooty, tarry bantling he nursed through its infantile ailments had grown into a giant whose labours returned gold galore to his owners and employers.

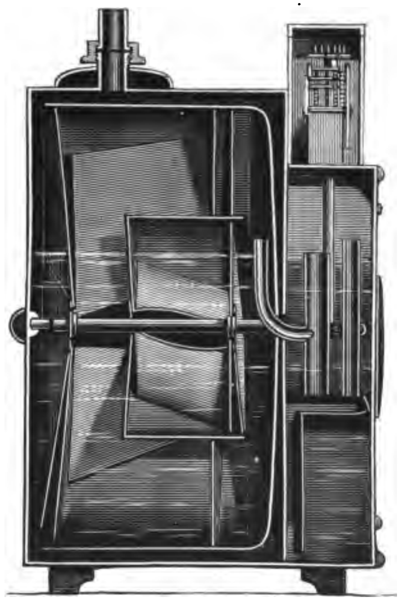

FIG. 5B.—Longitudinal section through meter case, showing compensating chamber for maintaining uniform level of water.

The possibility of carrying on a town gas undertaking at a profit was only realised when the supply to private consumers could be correctly measured; which was perfectly understood by Mr. Clegg himself, who has to his credit also the suggestion of the consumers' "dry" meter, the measuring instrument generally used in the United Kingdom to-day. The first practical meter, however, was of the "wet" order, in which the capacity of the measuring chambers was secured by sealing them, as they revolved

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round a horizontal axis under the impulsion of the moving stream of gas, in water maintained at a constant level (Figs. 5A. and 5B.). This type of meter is still used in gasworks to measure the production, and also for scientific purposes in which the greatest accuracy is required; but the trouble of regularly attending to it when fixed on private premises, and the liability to stoppage by frost, have led to the substitution of "dry" meters, with measuring chambers on the bellows principle. The standard of accuracy for all meters by which gas is measured for sale is the same—they are only stamped according to law when the margin of error is less than 3 per cent. slow, or 2 per cent. fast. This ensures that the turn of the scale shall always be in favour of the purchaser; and it is safe to aver that few commodities are more fairly measured or weighed on delivery than town gas.

The "dry" meter plays such an important part in the modern gas industry, that its construction deserves to be described in detail (see Fig. 6).

The effect of the introduction of the principle of measurement into the sale of town gas, was to place the industry upon a sound commercial footing. It was made possible to draw up a balance-sheet of working costs and returns; and with the reductions of the price of gas that followed, an increase of consumption ensued which redounded to the prosperity of the gas companies. For as soon as the financial corner was turned in the case of the original undertakings, competition began, and, in the case of the metropolis and other large towns which invited the speculation, was carried to extreme lengths. There was no monopoly, and in the densest centres of population the mains of three or four rival gas companies ran through the busiest streets. The most desirable customers were continually being importuned to transfer their patronage from one competing company to another; and they not

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infrequently played off these suitors against one another, with the result of getting gas for little or almost nothing. The gift of a show lamp or two for the outside of the premises was a taking bait for custom; and the gas company making the offer was quite equal to attaching this gratis service to the main of a rival! The consequence was that the competing companies maintained gangs of fighting navvies for purposes of attack and defence in this species of street warfare; and the roads were perpetually being broken up, until the nuisance and waste of money became intolerable, and the companies made a peace of exhaustion. Eventually, with the assistance of Parliament, the era of gas competition in the metropolis was terminated by districting the undertakings; and some years later their number was reduced to three by amalgamations. This process of consolidation was attended by the closing of expensive and inefficient small town manufacturing stations, and the concentration of production at sites where the work could be carried on under the most favourable conditions. In the provinces, gas competition likewise died out everywhere, usually by the absorption of the weaker concerns by the stronger; it being proved that the multiplication of public service undertakings of identical character in the same area is wasteful and opposed to the public interest, as well as being a hindrance to the advance of technical improvement.

Consideration in detail of the expedients adopted with the object of protecting the public from the evil consequences to be feared from the establishment of a system of virtual monopoly in town gas supply, at a period when there was no perfect or partially equivalent service, is reserved for a separate chapter. Suffice it to state here, that the acceptance on the part of the Legislature, and of responsible public opinion, of the economic truth that competition is not

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the way to provide town gas to the best advantage of all parties concerned, was accompanied by the adoption and active prosecution of two alternative courses of policy designed to attain this end. One pointed to the control of gas companies, in the sense of encouraging them to reduce their charges by offering a progressive bonus on lowered prices; the other consisted of transferring the gas supply to the local authority. Both systems are in full operation at the present time, and while neither can be truly described as being an unqualified success—for there is cheap gas, and gas which is not so cheap, to be had in England under both systems, and without them—it is at any rate true that nothing more effectual has been discovered and applied in any other country.

HOW GAS IS MADE.—The manufacture of town gas has necessarily remained essentially the same operation as when it was discovered that pit coal could be distilled off in a closed retort into the four distinct products, uncondensable combustible gas, burning in the air with a bright, luminous flame; water smelling strongly of ammonia; tar; and a residuum of coke. The process of distilling the coal, or "carbonising" it, as it is technically called, can be modified so as to obtain any particular product as the principal result, this result depending upon the temperature at which the operation is effected, and also upon the design and dimensions of the retort, for the same raw material. Thus, if the coal is filled into a large boot-leg shaped retort, moderately heated, the greater part of the distillate will be tar, oils, and ammoniacal liquor, with little gas and a friable, free-burning coke. At one time, when these fluid distillates and ammonia fetched a good price, several works were started for their manufacture from common coal; but the market failed, and the industry ceased to pay. At the present time, the only manufactures of the kind being

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carried on are the shale distilling works, making paraffin lamp oil, paraffin wax, etc., chiefly in the Lothians.

Coal is also extensively coked, at the pits, for conversion into the particular kind of fuel required for blast furnaces. In this case, although the fluid distillates may be recovered, and the gas resulting from the coking washed for the recovery of ammonia and benzol, it is the coke which is the product sought for, and the manufacture is located where the coal is, and the gas finds no market (Fig. 7).

The process of carbonisation can be followed from the

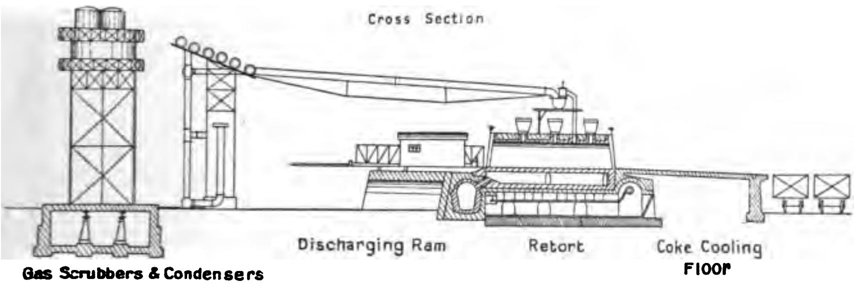

FIG. 7.—Retort coke oven (J. Tonge's "Coal").

accompanying illustration of a bench, or battery, of coke retorts taken by permission from Mr. J. Tonge's book on "Coal" (Constable's), wherein also an interesting description is given of the preparatory treatment of coal as brought to the surface, by washing, screening, etc., which is outside the scope of this book. The coking of coal in retorts of this kind, of which several arrangements are in use in this and other countries, does not differ in principle from the practice followed in gas manufacture. Indeed, in the neighbourhood of Boston, U.S.A., a congeries of gas distributing undertakings is supplied in bulk with gas from a coking plant of this character; and the gas for the city of

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Baltimore is made almost entirely at a coking works. The coal is taken to the bench in trucks, which run on rails laid upon the top of the brickwork. These trucks can be emptied through the bottom, down through charging holes in the top of the retorts. In the drawing there are three such lines of feed, so that a retort can be filled quickly throughout its length, and the charge raked level, in a very few minutes, and with a minimum of labour. The charge lies in the retort for twenty-four hours or longer, according to the system. It may weigh a ton or more. The character of the coal itself governs these details of the most convenient weight and consequent duration of the charge, some coals being much heavier and more sluggish in working off than others. Everything is disposed for and made subservient to the production of the hardest possible coke, which commands a high price. With this object the coal is washed to get rid of the dirt which would otherwise prevent it from coking; the charge is dropped into the retort all at once, to make a dense heap, which is sometimes pressed mechanically afterwards, with the same object.

Inasmuch as there is seldom any better use on the spot for the gas generated by the coking process, this is burnt under the retorts to provide the necessary heat, after having been washed for the recovery of the ammonia, the more valuable hydrocarbons, and the tar. Some of the gas may be utilised for generating the motive power required in the works; but, as a rule, in English coalfields where coking is carried on, there is more made than can be profitably utilised, so that the surplus burns to waste. In places where there is a market for the gas, as in the localities already named, it is usual to divide this product into two portions. The first few hours' gas after starting the carbonising of a charge of coal is richer than that

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which comes later, and is therefore drawn off separately for distribution as town gas. The later portion is burnt under the retorts.

It will be gathered from the preceding observations that the questions of how gas should be made at a profit, and whether the gas or the coke should be saved for sale, must be answered with reference to local market conditions; and this is the key to the economy of the whole industry. Coking, like charcoal burning, is a very ancient industry, but it has become sophisticated, and is no longer carried on under the simple rules of the primitive operators, who had a single eye to the one product for which they could command their price.

Originally metallurgical coke was made in "bee-hive" ovens, which are mere copies of the immemorial charcoal-burners' heaps of sticks covered with sods. The process of converting the coal into coke was one of partial combustion, the science of the burner consisting in allowing just so much air to enter the smouldering pile as would keep it going to the finish, and no more. If too little air was admitted, the pile went out, and all the labour and material were lost. On the other hand, too much air meant burning the coal, not coking it; and this was waste. In skilful hands, the resultant coke was, and is, of the best quality that it is possible to make, for which reason the bee-hive oven is far from being an obsolete kind of plant. The coke it turns out is in long and large columnar pieces, suggestive of "pulled bread," very hard and ringing, of a bright silvery grey colour, exhibiting traces of carbon in what might almost be described as a crystalline form, and occasionally hair-like. It is almost pure carbon (90 to 96 per cent.), most of the combustible impurities having disappeared by partial combustion in the long coking process. It sinks in water, whereas gas coke, as a rule, floats in

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water. Its great hardness enables it to sustain the superincumbent weight of the ironstone and fuel in the tallest blast furnaces built, and also to withstand the physical action of the strong air blast. Wherefore, having regard to the enormous stake which the ironmaster has in keeping his blast furnaces going to the very best advantage, he is by no means disposed to palter over a shilling or two per ton in the cost of coke, as represented by the economy of the coke-retort over the bee-hive method of manufacture.

Yet, notwithstanding the inferior physical structure of retort oven coke as first produced to bee-hive oven coke, the former has made its way in most coalfields, and has even made a bid for the *entrée* into gasworks. This is not likely to be granted generally, for various reasons. The first is that, as a rule, gasworks exist for the manufacture of gas, not of coke, which is to them a bye-product. The carbonisation of coal being a process absorbing heat, which has therefore to be supplied for the purpose, the question of whether the gas or the coke resulting from the operation shall be taxed with this object, goes to the root of the economics of the business. Where the coke is worth more than the gas, the latter is burnt under the retorts, as at the pit-head; whereas in most town districts the reverse is the case. Therefore, since the coke, although possessing considerable value, is of secondary consideration in town gas manufacture, the system of carbonisation is designed to obtain the best value from the coal in gas, which is not to be done by the same method as in coking, namely, by large and heavy charges. Quite the opposite rule, indeed, prevails in gas manufacture, the smallest charges of coal consistent with reasonable labour costs being preferred; and a proportion of the coke made being burnt under the retorts.

Gas manufacture, therefore, consists in carbonising coal

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for the sake, chiefly, of the gas; the other products of the raw material being appropriated as incidentals, by the name of "residuals," to reduce the cost of the gas into the holder. Considerations of the expense of transportation of the raw materials, and transmission of the gas through the mains, determine the location of the works with reference to the district of supply. The retorts in which the coal is carbonised are fireclay tubes, kept at a temperature as steadily as possible in the neighbourhood of 2,000° F. This is esteemed a good heat, and is the mainspring of the manufacture. Where the heats are poor, nothing else avails to secure profitable working. The coal is charged into the retorts at intervals of four to six hours, during which the gas and tar are driven off together as a thick smoke, which rises through pipes appropriately called "ascension pipes," and is collected into a large main where the heavier tar and water begin to separate out. The residual coke remains in the retorts until it is removed to make room for a fresh charge, and so on.

The appearance of a "bench" of horizontal retorts, which is the name given to a row of retort "settings," ranged side by side, is shown in several of the illustrations which follow. Up to the present time the bulk of the gas manufacture of the world has been carried on by means of these nests of tubular fire-clay retorts, which are grouped together over the furnace in fire-brick arches, with the object of economising fuel. The retorts are of various shapes in cross-section—round, oval, or like the letter ◠ with the flat side downward, about 21 inches wide by 15 inches high. The last is the form most generally used, although different gas engineers have their individual preferences in this regard. The retorts may be either "singles," in small works, or "throughs," in larger establishments. The former are about 10 feet long, with the back end closed

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and the front end provided with a cast-iron "mouthpiece" closed by a gas-tight lid, which is removable for the purposes of charging the coal and drawing out the coke. The mouthpiece also carries the bottom end of the "ascension pipe," through which the gas leaves the retort to be collected in the retort house mains. "Through" retorts,

FIG. 8.—Hand retort charging machine (Biggs-Wall).

as the name implies, are open tubes, with a mouthpiece at each end. They are about 20 feet long, and are worked by hand or machinery simultaneously from both ends. The idea is to save heat and the material and space for the back wall of "single" settings. They facilitate the charging of the retort with coal from either or both ends, and also the drawing or pushing out of the coke.

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Various ingenious mechanical appliances are in use to lighten or wholly supplant hand labour for this heavy work. The most obvious proceeding is to relieve the stoker from the strain of lifting the weight of the tools and the charge by some arrangement of hoisting and traversing tackle, while leaving the direction of the operations to his personal judgment. Excellent results are achieved in this way,

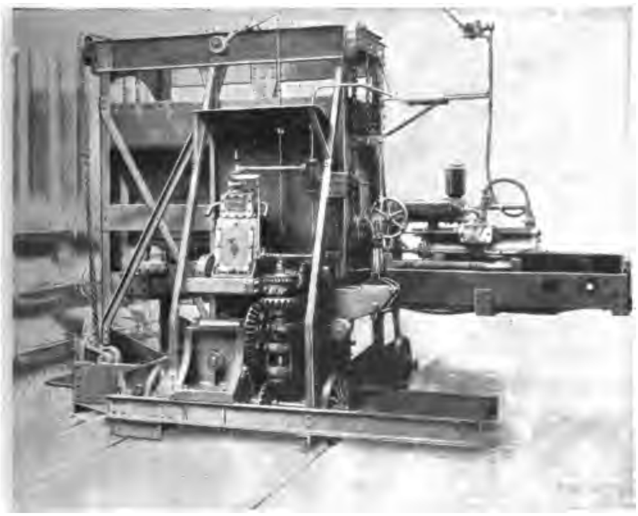

FIG. 9.—West's charging machine, driven by compressed air.

especially in small to medium-sized works, a type of the appliances employed being shown in Fig. 8.

The complete supersession of manual labour by power machinery is effected by apparatus such as is illustrated by Figs. 9, 9A, 9B. Other machines for the same purpose are driven by hydraulic or electric power, Figs. 10 and 10A.

Another largely used disposition of carbonising plant has

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the retorts set at an angle with the horizontal corresponding with the natural slope of repose of a heap of coal or coke, with a view to performing the operation of charging and discharging by the action of gravitation. Usually, in connection with carbonising plant of this kind, there is provided as complete an installation as circumstances permit of accessory coal elevating and coke handling plant (Fig. 11).

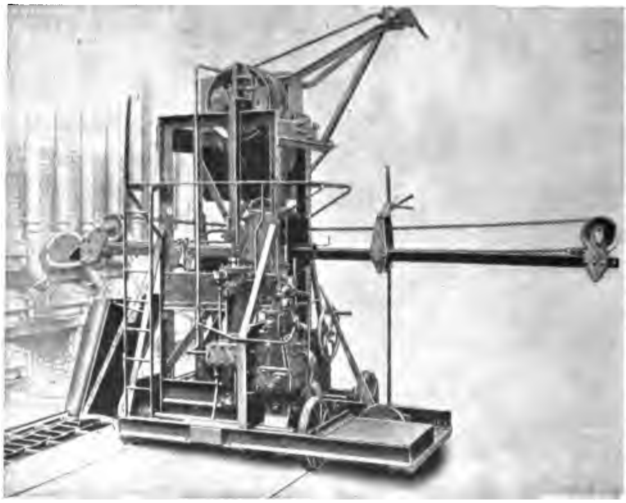

FIG. 9A.—West's drawing machine, driven by compressed air.

The charge of coal is supposed to lie evenly and of an uniform thickness all over the floor of the retort. It weighs, in the case of North of England coal, about 3 cwt. to 3½ cwt. for a single retort, and therefore twice this weight for a 20 foot horizontal retort. The duration of such a charge would be six hours. The charge of coal of this description would not occupy more than one-third of the height of the retort; but it swells in coking to double its original bulk.

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The retort and its management are the pivot upon which the whole of the business of successful gas manufacture turns. The best working conditions are a compromise

FIG. 9B.—West's combined charging and drawing machine, driven by compressed air.

between several conflicting requirements, with infinite modifications to suit technical, industrial, and local necessities. From the point of view of the gas manufacturer alone, small charges quickly worked off yield the best

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results. It is possible to obtain as much as 14,000 cubic feet per ton of good gas in this way from a quite ordinary

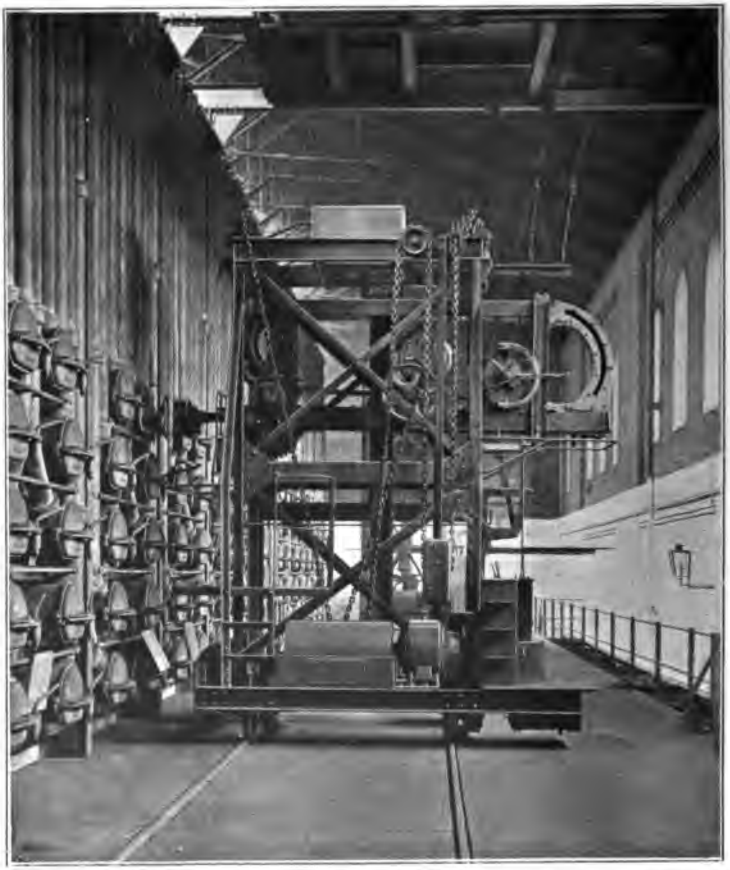

FIG. 10.—De Brouwer electric charging machine.

coal carbonised in ½-cwt. charges. This, however, is impracticable on a working scale, where hundreds and even

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thousands of tons of coal have to be passed through the retorts within twenty-four hours. The labour would be

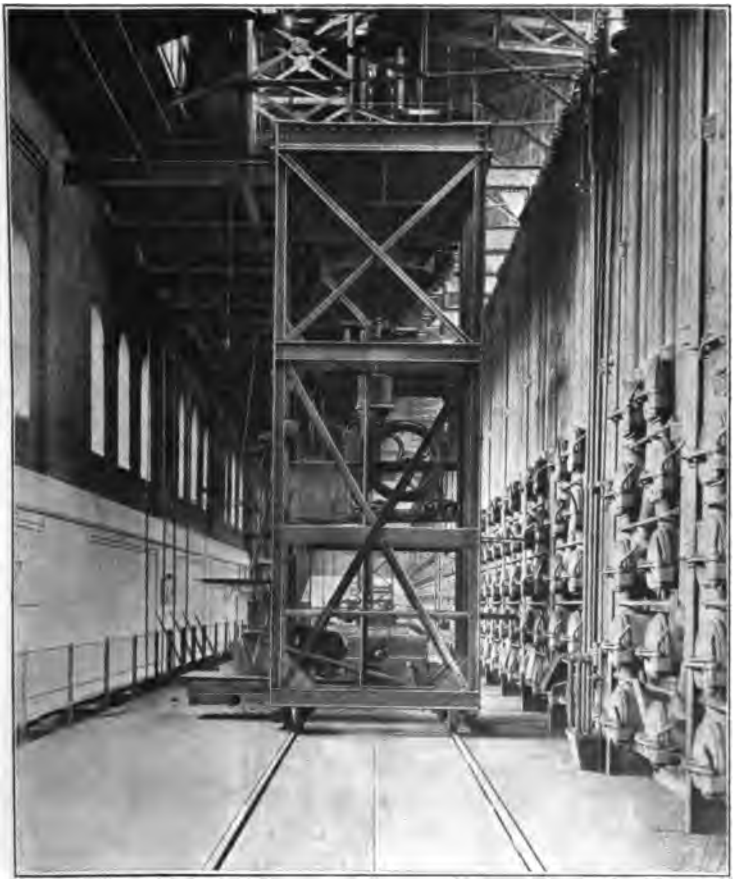

FIG. 10A.—De Brouwer-Jenkins electric ram discharging machine.

excessive on any ordinary system, and the incessant manipulation of the plant impossible. Still, it is the ideal

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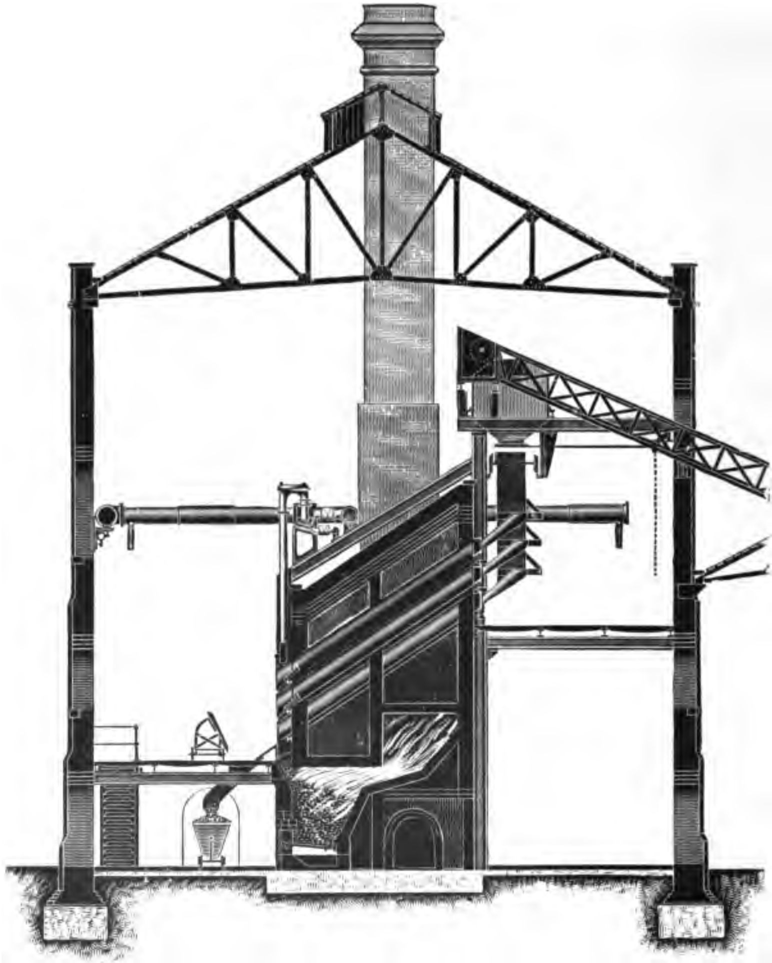

FIG. 11.—An inclined retort installation. Cross section.

condition for making the best of the raw material; and accordingly numerous inventive minds have been addressed

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to the solution of the problem presented by the mechanical difficulties of the case, so far with but partial success.

Although the idea of carbonising coal in small doses, either continuously or intermittently—in motion through the heated retort, or reposing in it for a sufficient period of time—appears to lie at the opposite pole from that of coke retort carbonisation, with its heavy charges of long duration, curiously enough there exists at the moment in gas engineering opinion an inkling that these extremes may be brought together with advantage. The link is presumed to consist of a retort placed in a vertical position. There is nothing new in the idea of an upright retort, the first cast-iron pots used by Murdoch to make coal gas in his small way being placed in this position for convenience' sake. Although the upright position looks at a first glance better suited for taking in coal than the horizontal retort, into which coal must be shovelled or otherwise deposited, yet its drawbacks have hitherto prevented its use in coal gas works. These drawbacks are, first, the difficulty of getting out the coke, which packs itself hard and tight in an upright tube that has been filled with coal by gravitation; and secondly, the difficulty of heating a long vertical tube with any reasonable consumption of fuel.

It has proved to be possible, however, by the employment of modern methods, to overcome both these ancient obstacles to the use of the vertical retort; and advances, which bid fair to be permanently successful, are now in progress on two distinct lines with the object of converting this disposition of the retort to the purposes of gas making. One aims at a combination of the obvious advantages of direct gravitation charging, to which the upright retort lends itself, with a continuous, or intermittent at brief intervals, mechanically-aided descent of the contents of the retort as the process of carbonisation proceeds, the coke being

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automatically withdrawn from the bottom end of the retort as fresh lots of coal are introduced at the top. In order to facilitate this operation, steam evolved from the quenching of the coke in water is allowed to ascend and percolate through the charge, becoming in the passage converted into "water gas," which mingles with the nascent coal gas. This action is also attended by a loosening of the coke, which prevents it from jambing in the retort. The success of this arrangement plainly depends upon the maintenance of a correct balance among all the working elements of the combination. The problem of economically heating the retort is solved by the modern system of firing by gas furnaces on the Siemens principle, in which the solid coke fuel is primarily gasified by a limited admission of air, and the carbon monoxide thus formed is completely burnt later in the place where its heat will do most good, by a second admixture of air that has been heated by the waste gases from the furnace.

The other system of vertical retort carbonising more resembles the coke-retort method of treating the coal, the charge being dropped into it in a mass and allowed to remain for twelve hours, or until it is so completely coked that it shrinks away from the hot surface of the retort, which is slightly tapered in order to permit the coke to drop out when the bottom lid is removed. Success in this arrangement depends upon the dimensions and form of the retort, and some other details which have been settled after elaborate, protracted, and expensive experimenting. It is not necessary for the retort to be vertical; any angle of inclination with the horizontal superior to the angle of repose of coal in a heap will fulfil the essential condition of the system, which is that the retort be full of coal. The effect of this condition is, that the carbonisation proceeds from the periphery of the charge and gradually extends

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inwards to its core, which remains uncaked to the last, thus forming a way of escape for the gas through what is still coal in an inconglomerate state. The results thus obtained are very promising, and many engineers believe that the coal gas manufacture of the future will probably be based upon this principle; but the details of the technic

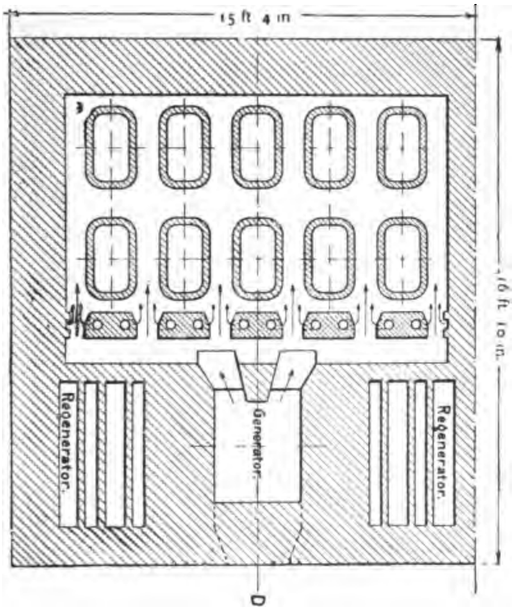

FIG. 12.—Vertical retorts (cross section).

and the chemistry of the operation have not yet been thoroughly worked out (Figs. 12 and 12A).

These matters differ in some important respects from the usual results of carbonising coal in horizontal retorts, or in retorts which are inclined at an angle not greater than that of the natural slope of a heap of coal, in which cases the retort is never quite filled up. This is the principle on

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which gas retorts have been worked from the beginnings of the industry—that the retort should not be crammed full of coal, but a clear space should always exist over the charge.

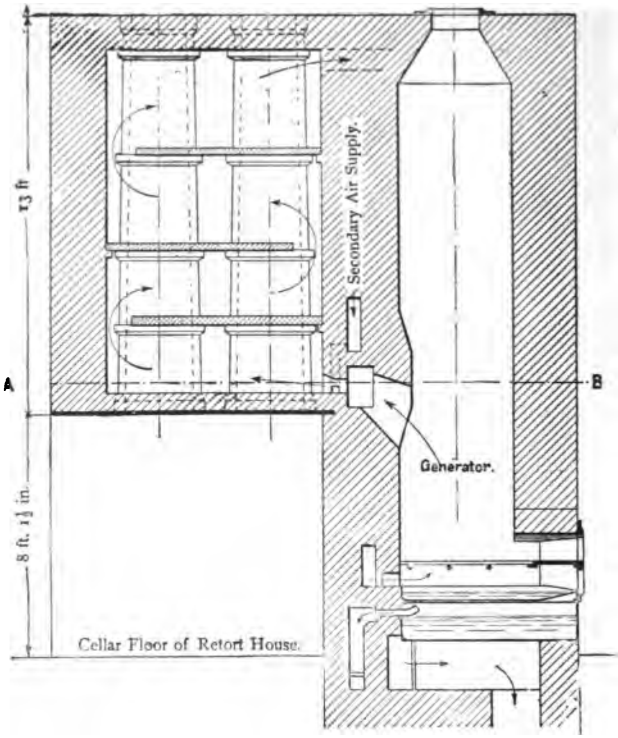

FIG. 12A.—Vertical Retorts. Sectional elevation.

The chief reason for this was to leave room for the insertion into the retort of the iron rake used in drawing out the coke; and it had incidentally a powerful influence on the result of the carbonising operation. It meant that the gas, as given off from the coal lying in contact with the hot

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floor of the retort, rose up into this highly heated space, through which it had to pass lengthwise of the retort to the mouthpiece and the ascension pipe. In its passage the gas was exposed to the heat of the upper half of the retort, and suffered a greater or less alteration of its composition according to the length of its travel. Meanwhile, the charge of coal would melt into a semi-fluid mass, if North of England or other coking coal, and give off whilst in this state a heavy, smoky, tarry gas, rich in the illuminating hydro-carbons, such as may be seen spurting out from the coal in a household fire. Part of this gas would be baked and altered in the clear space of the retort, leaving its most valuable constituent, carbon, behind as deposited graphite; which had to be periodically removed, or it would completely block the retort in time. As the period of the charge drew towards the end, the character of the effects produced inside the retort changed. The plastic mass of coal, having parted with its gaseous and liquid components, became solid again in the form of coke. The gas proceeding from the later period of the carbonising operation would be of a poorer quality, dry, and increasingly sulphurous. Indeed, the last squeeze of the charge might well be spared by the gas manufacturer, were it not that he must finish off his coke so as to be saleable; and also allow the retort to gather heat for the next charge.

It will be understood from the foregoing description of the ordinary course of carbonisation of coal in a retort with a clear space over the charge, that the product continually varies in character from the moment the charge of raw coal is introduced to the end, when the coke is ready to be drawn. An experience extending backwards through two or three generations of gas managers has taught how to adjust the working conditions so as to obtain the

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best average of commercial results in the respective commodities of gas, coke, tar, and ammonia; but, as already remarked, the whole scheme of operations upon this plan is a compromise. What is best for making gas is bad for making coke; and the same

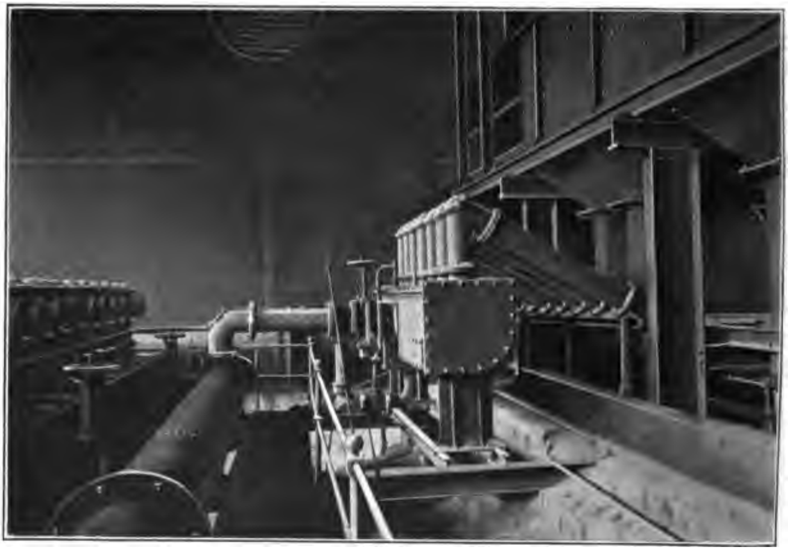

FIG. 13.—Arrangement of pipes over the retort bench for collecting the first fluid distillates.

difficulty extends to the production of tar, ammonia and cyanogen.

The gas as it comes away from the retort is a highly complex mixture of chemical elements and compounds. The following is a chemist's statement of the immediate results of carbonisation:—

"The greater part of the hydrogen of the original coal passes off, partly in combination with oxygen as aqueous vapour, and partly combined with carbon as marsh gas and

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olefiant gas or ethylene, together with smaller quantities of acetylene, benzol, and other hydro-carbons, while a

FIG. 14.—Condensers.

portion passes off in the free state. The nitrogen of the coal is driven off, combined with hydrogen, in the form of ammonia, and with carbon in the form of cyanogen, and

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the sulphur which is present in the original coal, in the form of iron pyrites or brasses, is evolved in two forms, namely, as sulphuretted hydrogen and as carbon bisulphide, and, according to some authorities, as sulphur dioxide.

"Part of the aqueous vapour driven off from the coal is likewise decomposed by the action of carbon at high temperature, forming carbonic acid, carbonic oxide, and free hydrogen. As the various gases leave the retort, and the diminished temperature permits chemical affinity to have more play, several of the substances previously alluded to recombine." (Hornby).

All the volatile products of carbonisation leave the retorts by the "ascension pipes," at a temperature sufficiently high to carry off the water and tarry matters in the state of vapour, the whole then being a dense, brown smoke. The temperature soon falls below the boiling points of the water and some of the oils, which therefore drop down in the liquid state in the pipe connections immediately following the ascension pipes (Fig. 13) and drain away to the tar and liquor wells. The same stage of the purifying operation is continued in the condensers (Fig. 14), where the gas is cooled to nearly the atmospheric temperature, leaving the rest of the fluids in the wells, with the exception of some mechanically suspended particles of tarry "fog." This is got rid of by friction against wetted coke, or boards, in a section of plant called the washers or scrubbers (Fig. 15). Here the gas is treated to a shower bath, first of its own condensed ammoniacal liquor, which becomes stronger in ammonia by the process. The strong ammoniacal liquor also absorbs a portion of the gaseous sulphur and carbon dioxide. The washing is completed with cold clean water, which has an affinity for the gaseous ammonia, and removes all of it but

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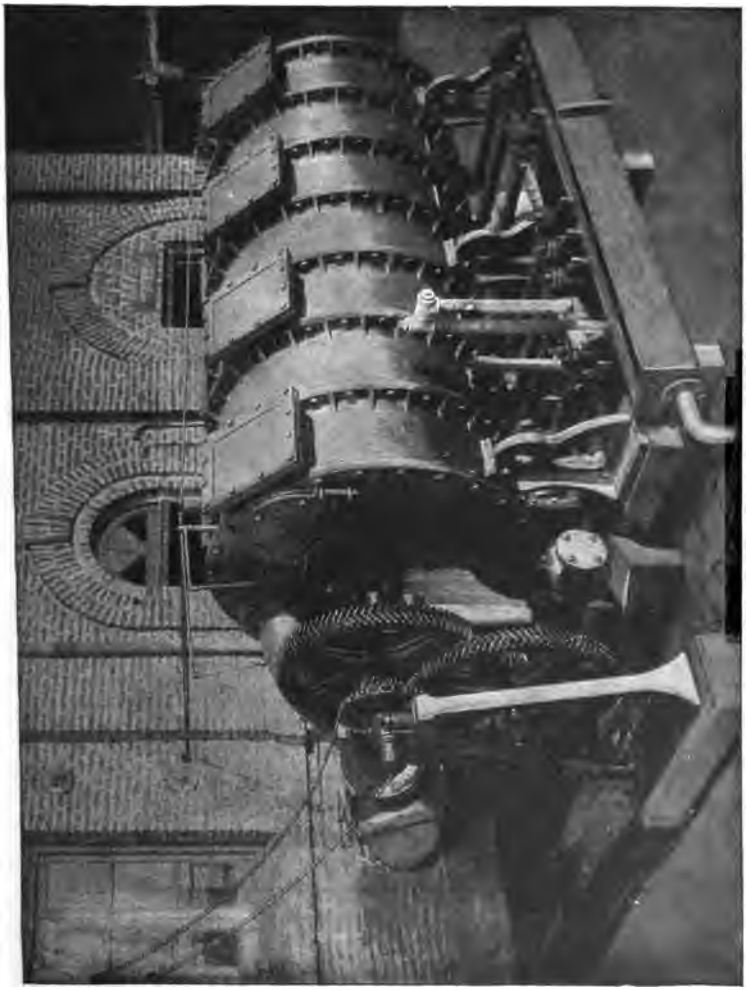

Fig. 15.—Washer-Scrubber.

the merest trace. In some cases the gas at this stage is washed with a solution of an iron salt in water, to recover the cyanogen.

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After this, the gas is passed through vessels containing slaked lime, or iron oxide, supported on trays or "grids," for the removal of its sulphur impurities and carbon dioxide. The sulphur readily combines with either lime or iron oxide, with the exception of a small residuum which has hitherto resisted every means employed to dissociate it from coal gas (Fig. 16). After slaked lime has performed its office, it has largely become converted into inert carbonate of lime, with some sulphur; and is then known as "gas lime," which is a useful dressing for grass

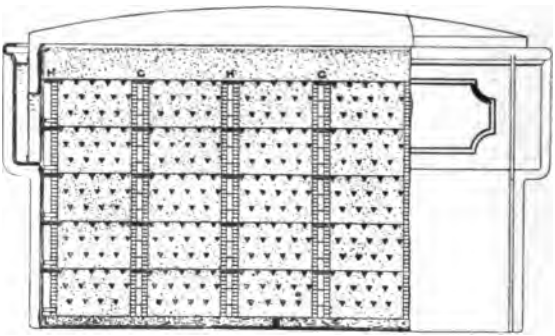

FIG. 16.—Purifier.

lands. Oxide of iron will go on absorbing sulphur from thoroughly washed gas, until so heavily charged with it as to be worth treatment for its recovery. The gas on leaving the last purifier is ready for sale.

Gas is measured on the works, for administrative reasons, by station meters; and stored in the large floating shells called gasholders until wanted. This storage, besides being a practical convenience and safeguard for the continuity of the supply, fulfils a highly important purpose in the economy of the industry. It compensates the working for the lack of correspondence between the irregularity of the

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demand, and the continuous production. In summer, when the greater number of shops and places of business never light up at all, the heaviest consumption of gas in a residential district is between eleven and one on Sunday mornings, while dinners are cooking; yet in no well organised gasworks is there any gas making on Sundays.

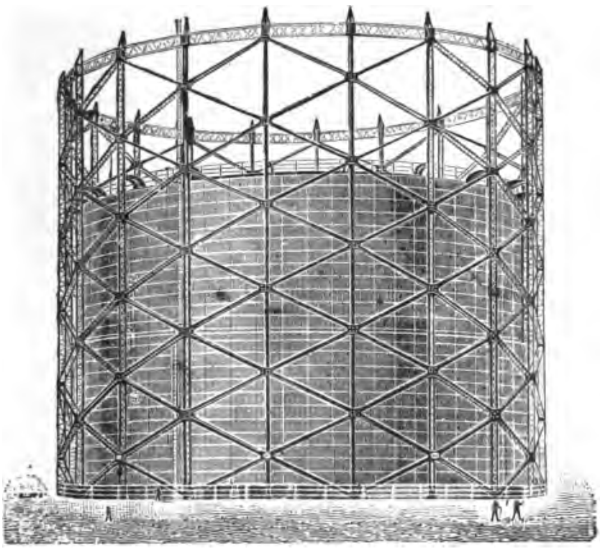

FIG. 17.—Gasholder.

The gas is simply drawn out of stock accumulated during the week, and keeps without deteriorating or wasting (Fig. 17).

The proportion of storage capacity in gasworks is usually about equal to the maximum twenty-four hours output; which enables the works manager to regulate the production on the most economical basis, with the minimum of stand-by expenses. The discharge of gas from the holders into the

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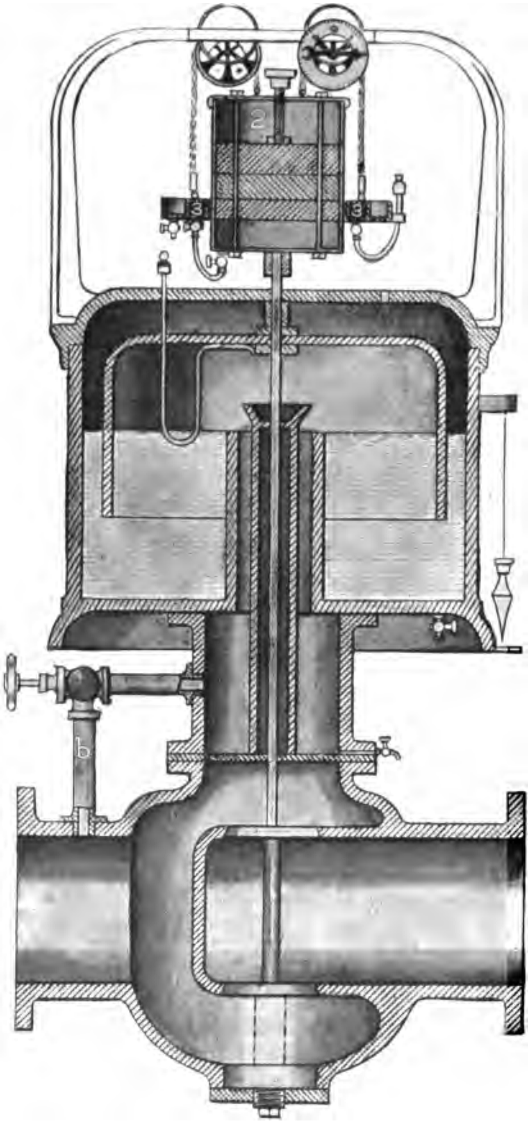

FIG. 18.—Connelly's automatic governor.

This apparatus needs only to be adjusted once to the maximum and minimum pressures required, when it will continue to automatically put on and take off the pressure according to the demand at any time, and in strict proportion to the maximum and minimum for which it is set.

The governor consists of a bell in a tank with water seal, and connected by a rod with two valves of the disc type. The outlet pressure is communicated to the bell by means of the small pipe (*b*), an increase causing the bell to rise and a decrease to fall.

In use the annular ring is sufficiently weighted to give the minimum pressure required, and a quantity of mercury is introduced to give the necessary maximum, and this mercury is free to flow between the glass receptacle (2) and annular ring (3) by means of a rubber tube. As the demand for gas increases, the bell falls, the glass receptacle which is

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town mains is automatic, being controlled by an ingenious apparatus called a "governor," which opens or shuts the main gas valves according to the pressure on the town side. When the pressure backs up against the governor, owing to a diminished demand upon the distributing mains, the connection with the gasholders is throttled in exact proportion, and enlarged again the moment that more gas is required in the district (Fig. 18). Sometimes, in spring and autumn, dense local fogs appear in parts of the district without the briefest warning, whilst the atmosphere elsewhere is clear. On these occasions the benefit of the gasholder and its accessories is most marked, as it responds instantly to the general lighting-up in the darkened region, which may only last for a few minutes.

There are several other forms of the same order of apparatus, as Cowan's "pressure changer"; which are the equivalent of the electrician's "switch board," and are more or less automatic in their action, according to the requirements.

The economy of gas manufacture is carried to a high pitch. Gasworks are designed and organised as engineering works in which large quantities of heavy and bulky materials have to be taken in and sent out, and handled throughout with the least expense. The weight of coal carbonised daily in a gasworks of the first magnitude far exceeds the fuel consumption of any "power house" in existence, running

---

rigidly fixed to it follows, and the annular ring rises, causing mercury to flow from one to the other, thus increasing the weight on the bell, giving more valve opening, and consequently more pressure; whilst a decrease in the demand reverses this movement, so decreasing the pressure. If a record is taken it will show at a glance the hours of cooking and lighting, the latter of course varying according to the weather; but no matter what the difference in the daylight may be, even on two consecutive days, the governor attends to all requirements without any manipulation whatever.

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well into four figures of tons. How completely this raw material is accounted for will appear by the following table, which also gives a comprehensive statement of the results of the daily operations of a gasworks.

STATEMENT OF THE PRODUCTS OBTAINED BY THE CARBONISATION, IN NORMAL HORIZONTAL RETORTS, OF DERBYSHIRE UNSCREENED GAS NUTS. BY J. H. BROWN, NOTTINGHAM, 1905. (*Proc. Inst. G.E.*)

	September 6th to 7th.	September 7th to 8th.	September 8th to 9th.	Averages.
Duration of test	24 hours	24 hours	24 hours	
Number of charges	48	48	48	
Weight per charge	2¼ cwt.	2¼ cwt.	2¼ cwt.	
Total weight	5 tons 4 cwt.	5 tons 4 cwt.	5 tons 4 cwt.	
Charges worked off in	5 hours	5 hours	5 hours	
Condition of retorts	very good working heat	very good working heat	very good working heat	
Gas made, corrected	60,991	63,985	65,348	
,, per ton	11,295	11,849	12,101	11,748
Crude gas	11,514	12,033	12,310	11,952
Illuminating power of gas	15·34	15·33	15·11	15·26
Sperm, lbs. per ton	549·05	622·78	626·9	614·58
Calorific power of gas	652-591	639-578	625-565	639-578 gross & net
B.Th.U. per ton, net, millions	6·175	6·849	6·837	6·787
Crude gas contains H_2S per cent.	0·7	0·6	?	0·7
,, ,, CO_2 ,,	1·2	1·1	0·76	1·0
,, ,, O ,,	2·2	2·6	2·0	2·3
Grains NH_3 per 100 cub. ft.	80·56	57	?	69
,, sulp. cpds. ,, ,,	13·73	22·01	36·73	say, 24
Purified Gas, sp. gr.	0·476	0·456	0·456	0·463
Analysis CO_2	1·4	0·8	1·0	1·1
,, O	1·1	1·3	1·8	1·4
,, Cn Hm	4·1	3·9	4·0	4·0
,, Co	8·4	7·8	8·8	8·3
Methane series	27·5	26·3	25·9	26·5
H	50·3	54·3	52·5	52·4
N	7·2	5·6	6·0	6·3

	Total for 3 days.			Averages.
	tons.	cwt.	lb.	
Coke made	9	3	0	
Breeze ,,	0	11	8	
Dirt ,,	0	12	1	
Bats ,,		—		
Total residue	10	7	0	Coke 12·87 cwt. per ton

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STATEMENT OF THE PRODUCTS, ETC.—*continued.*

	Total for 3 days.	Averages.
Quality of coke	0·7	
Ash in coke	5·24	
Tar made, gallons	257	
,, per ton	15·87	Tar 15·87 per ton.
Specific gravity of tar	1·130	
Fixed carbon in tar, per cent.	22·27	
Volatile matter	66·73	
Liquor made, gallons, 10 oz.	356	
,, ,, ,, per ton	22	
Lls. sulphate of ammonia per ton equivalent	18·52	Liquor 18·52 lb. s/a per ton.

Analysis of Ash from Coke

SiO_2	= 45·92	per cent.
CaO	= 18·19	,,
MgO	= 3·97	,,
Fe_2O_3	= 14·45	,,
Al_2O_3	= 14·59	,,
Alkalies	= 2·17	,,
SO_4	= 0·56	,,
	99·85	,,

Coal, bright, shining black. Contains a few thin layers of charcoal in the plane of stratification. Fracture cubical with a few laminæ of carbonate of lime and traces of sulphide of iron. Cross fracture irregular, showing a bright resinous surface. Streak, reddish brown. When heated the coal fuses and swells up considerably. When burned completely away it leaves a light brown ash. Per cent. ash in coal = 3·28.

	Weights per ton.
Gas	437 lb.
Coke	1,432 ,,
Tar	179 ,,
Liquor	225 ,, *
H_2S	14 ,,
CO_2	7 ,,
CS_2 and CN	say 6 ,,
Total	2,300 lbs.*

* Includes water used in washing.

The strength of liquor is expressed in terms of the quantity of sulphuric acid required per gallon to neutralise the ammonia content. Thus 10 oz. liquor requires 10 oz. of the acid per gallon.

The cost of gas manufacture depends upon numerous

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elements of expense which differ in almost every case. The most influential, in respect to the price at which it is possible to sell the gas at the profit allowed the undertakers by their private Act of Parliament, is the charge for capital, which is usually an affair of history. British gas companies are not as a rule allowed to reduce their capital, but the gas capital of municipalities, like all their other loans, is reducible by sinking fund. Owing to considerations which must be sufficiently obvious, few old-established gas undertakings in the United Kingdom have so low a capital as they might set up in business upon at the present day. On the other hand, in cases where the undertaking has grown considerably, the greater cheapness of the extensions has lightened the whole capital burden. The scale of the undertaking, also, affects the standing charges within a certain range, small works being at a disadvantage in this respect. It does not follow, however, that the very largest concerns are necessarily the best off as regards fixed charges, bulky outputs having their drawbacks as well as their advantages. The capital charges of the Metropolitan Gas Companies run from 8*d.* to 1*s.* per 1,000 cubic feet of gas sold. The works costs, in the same typical undertakings, range from 10½*d.* to 1*s.* 2½*d.* Rates and taxes vary from 1¾*d.* to 3¼*d.* (It will be perceived by this statement, that even where a gas undertaking is not "municipalised," it may contribute as much to the local exchequer as if it were.) These elements make up the price of gas everywhere; and as the accounts are published, it is always easy to obtain the actual figures in any case.

There is an entry in analyses of gasworks accounts which requires some explanation. It appears under the title "Unaccounted-for gas," being the difference between the volume of gas registered as manufactured, and that paid for and used on the works. It usually amounts in ordinary

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cases to 5 per cent. of the output, more or less. If the quantity is much higher, as it often is in mining districts, where earth settlements are frequent, it means undue leakage. This figure is one to which the careful gas manager always devotes particular attention, as its magnitude is understood to indicate the condition of the distributing plant. It has been too readily assumed, however, by some without technical knowledge of the subject, that this figure means leakage in every case, thus leading to the drawing of fancy pictures of the condition of the subsoil of towns, and other imaginary consequences of the continual escape of so much gas. In fact, although the risk of leakage, as already remarked, is one against which every gas manager is perpetually on his guard, very little gas indeed is actually lost in this way in localities of an ordinary character as regards subsoil stability. In the newer streets of London, subway tunnels are provided for the gas pipes, and these are perfectly tight. The same condition would exist in the case of gas pipes buried under roadways, but for the occasional damage done to them by traction engines, road rollers, and other exceptionally trying traffic. Breakages do occur from such causes, resulting in waste of gas, but they are usually detected before long. The figure in question is really the cover of every sort of shortage. Thus, it has already been explained that consumers' meters may show a turn of 1 per cent. against the vendors, which helps to swell the unaccounted-for figure. The supply to the multitudinous public street lamps is not measured, but may be regulated by small governors supposed to pass the contracted-for quantity of gas. Any excess is unaccounted-for. Besides all these and other "loose ends" which might be mentioned, the effects of varying atmospheric temperature and barometric pressure make it physically impossible to secure an exact correspondence between the volumes of gas measured in

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Safety Gas Seal. Superheater. Carburettor. Producer.

FIG. 19.—Carburetted Water Gas Plant at Liverpool (Humphreys and Glasgow's system).

bulk before storage, and in detail at the points of consumption. Hence the appearance in the best-managed gas companies' books of an entry so open to misconstruction as this of "Unaccounted-for gas."

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An important ancillary of coal gas, in town gas manufacture, is "carburetted water gas." This kind of illuminating and fuel gas is made, in British gasworks, from coke, the residual from coal carbonisation, and steam, with an admixture of heavy mineral oil. It originated, in the form adopted in the British gas industry, in the United States, and has spread over the world so rapidly of late years that it is claimed to constitute one-third of the bulk of the gas consumed by English-speaking peoples. The reasons for this are the comparative cheapness of the plant both in first cost and in working, the small ground space occupied by it, the facility with which an auxiliary plant of the kind can be got into full work at short notice, and one or two other recommendations so well appreciated by gasworks managers, that where a good plant has once been put down it is never turned out. The type of plant now in question is that known as the "Lowe." It comprises a cupola, or "generator," with air and steam blast connections which enable the coke fire within to be raised by the former to a high pitch of incandescence, whereupon the air is shut off, and steam turned on, which decomposes by contact with the glowing carbon, forming what is technically termed "blue," or non-luminous water gas. This latter operation cools the contents of the cupola, and it is therefore only continued for a few minutes, when the steam is shut off and the air blast resumed in order to raise the fuel to its former state of high incandescence. The air blast, after doing its work upon the coke in the cupola, is led through another similar vessel lined and filled with firebrick chequer-work, called the "carburettor," to which it imparts most of its own sensible heat. It next passes with the same purpose through a third vessel, similar to the "carburettor," which is called the "superheater," after which it escapes by a chimney. The steam, however, as converted in the cupola

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into water gas, follows the same course as the air blast, with the difference that it is met in the carburettor with a spray of oil, quickly gasified by the heat of its surroundings. Water gas and oil gas thus travel onward in company to the superheater, whose heat finally cements their union, and the current of "carburetted water gas" is drawn off through a pipe to mix with the coal gas being made at the same time. Such, in brief, is the process of manufacture of carburetted water gas. It is quite as permanent as coal gas, its only residual being a light tar.

Carburetted water gas was originally adopted in the United Kingdom at the period when the native cannel coal, which was required to enrich the gas manufactured from common coal to the illuminating power then in vogue, was becoming scarce and dear. This was about the year 1890. It was at first, therefore, made of relatively high illuminating power—say 21 or 22 candles—but when the standard of illuminating power for town gas was lowered, as already recounted, this gas was correspondingly reduced from the grade of an enricher to that of the bulk production. This was merely a matter of diminishing the proportion of oil gasified. The manufacture of carburetted water gas in British gasworks has largely increased under the modern conditions, its economy being especially felt where the coal has to be transported to the works by land carriage. In such circumstances its cost into the holders is about the same as that of coal gas, or slightly less. Some agitation against the admixture of carburetted water gas with coal gas has been attempted, as might be expected when an ancient monopoly is threatened, the fear being expressed that the comparatively high proportion of the poisonous gas, carbon monoxide, in the combined product would prove a menace to public safety. A Home Office Committee inquired into the matter, but no action was taken, the

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evidence of increased risk being inconclusive. Since then the manufacture has so greatly extended in municipal as well as privately-owned gasworks, that it would be extremely difficult to restrict it even if such a course were indicated as justified by a sufficient body of testimony, which is not the case.

The percentage composition of purified carburetted water gas of $20\frac{3}{4}$-candle power, made in London, is given as follows :—

Hydrogen	29·35	Combustibles and Illuminants.
Carbon monoxide	33·19	
Marsh gas	20·48	
Light-giving hydrocarbons	11·32	
Nitrogen	5·17	Inert gases.
Carbon dioxide	0·17	
Oxygen	0·32	
	100·00	

This description of gas is largely supplied in the United States, anthracite coal being used as the carbon material. In England, as already stated, coke resulting from the coal gas manufacture is invariably used for this purpose, the gas output of the works being therefore a mixture of about the percentage composition given on p. 5. Such a mixture is not practically distinguishable in useful properties from all-coal gas, except that its flame is rather shorter than a flame of coal gas of equal quality.

There is one consideration respecting the supplementing of coal gas with carburetted water gas which is deserving of mention, as an argument for the practice. It is that by this means, and by this alone, so far as existing technical knowledge goes, the high fuel value of the world's production of heavy petroleum oils, unfit for burning in lamps, is made available for the public service. It is scarcely necessary to

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labour the point of the great economical importance of this market for these mineral oils, which form the greater portion of the crude petroleum output of every field. The only other use for them is for direct burning as fuel in special furnaces of marine and land boilers. Only in a limited number of localities, however, can the oils be laid down at a price corresponding to their fuel value, and the quantity available is far from being sufficient to supersede coal generally. Fortunately for the petroleum and allied interests, including the shipping, gas oil is saleable for about 50 per cent. more money than oil fuel, so that the bulk need not be wasted, as it otherwise would be.

In the manufacture of carburetted water gas after the English fashion, about three gallons of heavy oil, itself a residual of petroleum refining, and 40 to 50 lbs. of coke inclusive of boiler fuel, go to make 1,000 cubic feet of the finished product. In no other way could these residual matters reappear so efficiently as raw materials of a high-class fuel and illuminant. It is a better market for both than any other. Incidentally, the coal resources of the country are sensibly spared by this manufacture, in which 30 gallons of oil and 3 cwt. of coke take the place of a ton of gas coal.

"Blue" water gas—*i.e.*, the product of passing steam through a bed of glowing carbon in the form of anthracite coal, or coke—is not suitable for general distribution as a gaseous fuel. It is non-luminous. Its percentage composition averages as follows, when made with coke:—

Hydrogen . . .	51·92	Combustibles.
Carbon monoxide . .	39·62	
Marsh gas . . .	0·78	
Nitrogen	3·46	Inert gases.
Carbon dioxide . .	4·22	
	100·00	

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This gas has a calorific power of about 300 B.Th.U. net, and requires 3·17 times its volume of air to burn it. The objections to its distribution as a town gas, apart from its non-luminous character, and the risk attached to possible leakage of a highly-poisonous inodorous gas, refer to the intensity of its flame temperature and the rapidity of its ignition when mixed with air in the bunsen burner. It "burns," rather than warms, being only really convenient for welding iron. Its atmospheric ignition is too explosive. Outside a gasworks or a blacksmith's shop, therefore, it may be truly said that nobody has any use for "blue" water gas.

It is manufactured to some extent for mixing with coal gas, either by itself, or carburetted by the addition of benzol. At one time it was thought that oil might be economically carbonised in retorts, like coal, and the gas either used to enrich coal gas, or to carburet water gas. There is no technical difficulty in making pure oil gas, as is proved by the practice of lighting railway trains by such gas, which has the recommendation for this purpose of bearing compression without too much loss of illuminating power. This compressed oil gas is conveniently carried in cylinders attached to railway carriages, and serves both for lighting and cooking. It cannot, however, be manufactured advantageously on the scale required of town gas manufacture, oil carbonising retorts being slow of operation, and requiring an impossible amount of space for anything like a large output.

As employed to mix with coal gas, "blue" water gas is made by plant of the "Dellwik," "Methane-Hydrogen," "Kramers and Aarts," or other systems based on the method of producing the water gas from steam and coke in a simple cupola, by which it is possible to obtain nearly 70,000 cubic feet of such gas from a ton of coke in the best condition, or say 60,000 cubic feet from a ton of coke

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in average working. It is found advantageous under favourable conditions to add a proportion of this gas to common coal gas. Or, the water gas can be carburetted by the addition of benzol, a volatile residual hydrocarbon of tar distillation and a bye-product of the blast-furnace coke manufacture, and so added to the bulk of the output as a luminous auxiliary. The question of the expediency of these processes is for the manufacturer, who must be guided by the local values of the raw materials, of his labour, consideration of the condition of his works, and many other cares with which the public has no concern. So long as the standard of quality of the town gas is properly maintained, the industrial problems of the manufacture can be classified as revolving round the central consideration of value for money, which in the end affects supplier and consumer in exactly the same way.

Schemes have been propounded, and in a few instances tried, for the supply of towns with a cheaper and inferior kind of gas as compared with the universal commodity of which we have been writing, to serve as "fuel gas." A brief examination of this proposition will also serve to show why gas companies and local authorities, who have a perfectly free hand in this enterprise, go on supplying the particular class of town gas known by this title everywhere. The technic of gas manufacture recognises the existence of a cheaper article to *make*, but not to *distribute* for general consumption. This is the distinction.

Any inquiry into the economics of gas supply must begin with the inquiry, "Why gas?" With respect to any proposed use of gas, it is advisable to first put the question whether this is really the best means of going to work. For there is no magic about the gaseous form of fuel, to render it preferable to the solid, or the fluid form, in all cases. The question of lighting is different. In times now past,

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when gas lighting was the only available means of obtaining the desired effect, the supremacy of luminous gas over any non-luminous variety of the commodity was unchallengeable, as it still remains. But there is some superficial reason for the inquiry whether the same make of gas is best for fuel purposes, requiring in many cases a large bulk of the combustible.

Upon facing this question, the preliminary query must be put as to what is the best private practice in the particular case. Town gas supply started as a private convenience and economy, before it was organised into a public service. The same remark applies to the larger applications of other gas. It must be shown to be the favourite of fuel users, before its public supply can be hopefully undertaken as a separate undertaking. This proof fails. In the United States, there were at one time 27 public "fuel gas" companies, including undertakings in Chicago, Boston, and St. Louis. They all came to grief. The reason was that such gas as they made showed no advantage over coal for any purpose to which both were applicable; and it had no other uses. As compared with the higher-priced town gas, it cost a very little less to make, but just as much to distribute; and being of lower heat value, the works, mains, services, meters, etc., had to be larger than is necessary to deliver an equal quantity of heat in the same time by illuminating gas. The capital investment *pro ratâ*, therefore, became excessive.

What is distinctively called "fuel gas," to distinguish it from town gas, is also classified by the names of "producer gas," "Dowson gas," "Mond gas," and lately "suction gas." These names refer to a type of gaseous combustible, non-luminous, usually impure, and of low calorific power, produced by the imperfect combustion of coal or coke with air alone, or with air and a certain proportion of steam. "Producer" gas, made from coal or coke, and air, is

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admittedly too poor to carry economically any distance from the producer. It is, therefore, only locally used for heating furnaces required to be kept at a constant temperature, as the settings of retorts in gasworks. In itself it shows no economy over solid fuel; but inasmuch as it lends itself to heat "regeneration" *i.e.*, the economy of warming, by the waste gases of combustion, the air supply to the furnace, it practically does effect a considerable saving of the raw fuel. It is useless, however, where the heating is intermittent; and the cost of the structural dispositions is considerable. A sample from a Siemens gas plant using coal shows the following percentage composition:—

Hydrogen	8·6	Combustibles, 35·4.
Carbon monoxide	24·4	
Marsh gas	2·4	
Nitrogen	59·4	Inert gases, 64·6.
Carbon dioxide	5·2	
	100·0	

This gas has a calorific power of about 110 B.Th.U., and requires about an equal volume of air to burn it. The gas will scarcely ignite cold. It is, therefore, necessary either to use it straightway as made, while sensibly hot, or to reheat it at the point of combustion. It is never purified, and yields no bye-products.

A stronger fuel gas is that called after the principal improver of the process of manufacturing it, Mr. J. E. Dowson. "Dowson" gas is a product of passing air under pressure, together with as much steam as can be introduced without too much reduction of the fire temperature, through glowing anthracite coal, or coke. Its continuous production is therefore a question of hitting and maintaining the happy mean of fire, air, and steam. This was the kind of "fuel

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gas" which the American companies already referred to dealt in, with such disastrous financial results. There was no market for it before the gas engine was made a commercial success by Dr. Otto, about 1880. Since then, Dowson "power" gas, as it has come to be called, has been extensively made for this application; always, however, on the spot.

A sample of very good Dowson gas, made from anthracite, showed the following percentage composition:—

Hydrogen . . .	15·3	Combustibles, 44·3.
Carbon monoxide .	27·6	
Marsh gas . .	1·4	
Nitrogen . . .	51·8	Inert gases, 55·7.
Carbon dioxide . .	3·9	
	100·0	

It had a calorific power of 163 B.Th.U. (gross) per cubic foot, and required 1·15 vols. of air to burn it. This gas is made by blowing in the air and steam to the fuel in the producer, and the plant is therefore distinguished as being of the "pressure" variety. A small gasholder is usually included in a power and fuel gas set of this type, to equalise the production to the demand, and also to provide a store of gas to start with. This accessory apparatus costs money; and occupies ground space, which is not always available. Consequently, of late years preference has been shown, where the gas is only to be used for driving an engine, for a simplified form of plant called "suction gas plant," from the circumstance of the air and steam being drawn into and through the fuel in the producer, by the movement of the piston of the engine cylinder itself. The subject of gas power generation will be discussed later; but as regards

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the operation of suction power gas plant, it appears that its convenience and compactness have to be paid for by a weaker gas, the reduction of the engine power being estimated by Messrs. Dowson and Larter at 7 per cent. The net calorific power of suction gas is not much, if anything, higher than common Siemens' producer gas (*ante*), showing only about 37 per cent. of combustibles, and taking an equal volume of air to burn it. As there is no reserve, the best class of fuel is necessary to ensure the regular working of these producers.

The only other distinct make of fuel gas known is "Mond" gas, called after its inventor, Dr. Ludwig Mond. It differs from the others in being a low temperature product, which is brought about by passing a very large quantity of steam through the cupola. The raw material is bituminous coal, and the objects of the excess of steam (two-and-a-half times the weight of the coal gasified) are to prevent the formation of clinker, which would clog the producer, and to absorb the ammonia of the coal. In order to enable so much steam to pass through the fire without extinguishing it, a highly elaborate and ingenious system of heat recuperation is provided. The excess steam is not decomposed, as the steam is in water gas and Dowson plant; but condenses in the form of water out of the gas as it cools, carrying the ammonia with it.

The average percentage composition of Mond gas differs when the ammonia is recovered, which is only worth doing in the largest plants, and when it is left in. The calorific power does not differ much, however, being given as about 155 B.Th.U. (gross). It requires 1·10 vols. of air to burn it.

It will be seen by the foregoing particulars of industrial and commercial gas manufacturing systems, that town gas is a far stronger fuel than any of the specially named "fuel" or "power" gases. Ranged in order of calorific

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power, net, the comparison of all known manufactured full gases comes out as follows:—

Cheapest town gas B.Th.U. per cubic foot		500 to 550
"Blue" water gas (non-luminous)	.	280 ,, 300
"Dowson" pressure gas	,, . . .	135 ,, 145
"Mond" gas	,, . . .	135 ,, 145
Suction gas	,, . . .	110 ,, 120
Siemens' producer gas	,, . . .	100 ,, 120

So that, all other things being equal, it would need mains, service pipes, meters, and all other necessary apparatus of proportionately greater capacity, to carry any of these weak gases in sufficient equivalent volume to do the work of town gas. The cost of purifying them from sulphuretted hydrogen would be excessive, on account of the bulk to be dealt with; and if this purification were omitted, a serious nuisance would ensue, wherever the gas might be burnt. Inasmuch, moreover, as these gases are twice as heavy as town gas, the transmission of them would require more power, and be costlier still. Therefore, whilst circumstances may favour the private manufacture of one or another variety of "producer" gas, for consumption on the spot, it would not pay to distribute any of them for general consumption, even if they were capable of subserving all the uses of town gas, which is not the case.

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CHAPTER III.

THE BYE-PRODUCTS OF COAL GAS MANUFACTURE.

The residual products of gas manufacture from coal—Coke—Coal tar—Products of distillation of coal tar—The method of distilling tar—Short history of the origin and development of the coal tar products industry—The work of Perkin—Commercial uses of coal tar products—Ammonia recovery—Recovery of cyanogen compounds—Recovery of sulphur—Account of the tar and liquor works of The Gas Light and Coke Company and list of the products, with their chief uses—General view of the economy of the treatment of coal in gas manufacture—The economics of a chief product, and of residuals.

In the previous chapter, at p. 60, there is given a very complete and accurate statement of the results of carbonising a sample of gas coal. This showed that besides the gas, which weighed 437 lbs., one ton of coal yielded the following valuable products:—

	Lbs.
Coke	1,432
Tar	179
Sulphate of ammonia	18½

These are the products of coal carbonisation, in town gas works, which are commonly designated "residuals." Sometimes a cyanogen salt is recovered also, but this is not commonly done.

Coke is the most valuable residual of coal gas manufacture. The works itself takes the first toll of it, for fuel to heat the retort furnaces; and also for the carburetted

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or "blue" water gas auxiliary plant, if any. In handling it a portion becomes crushed, and is then called "breeze," which is also burnt by forced draught in the boiler furnaces, or sold off for a similar use, or as the "agglomerate" in a light kind of Portland cement concrete much used by builders. This residual sells for a large proportion of the cost of the coal, being a strong, smokeless fuel. As it requires a good draught in order to burn well and brightly, it is best adapted for burning in close stoves. Except being broken into a suitable size for small stoves, it is not treated in any way for the market. Coke from vertical retorts is denser than the ordinary, more resembling the product of coke-retorts.

FIG. 20.—The "Quaker" Grate for burning coke.

Quite recently (June, 1907) projects have been started simultaneously in various quarters for the manufacture of

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a special description of gas coke by carbonising coal at a low temperature, which has the effect of leaving some of the volatile components of the coal in the coke, instead of their being converted into gas, as in ordinary gas manufacture. This variety of coke ignites readily in open grates, and burns with a short, hot, smokeless flame. It has been called "coalite," "carbo," and other trade names. The other products of carbonising coal at a low temperature, with the particular object of making this flaming coke, naturally differ from those obtained either from metallurgical coke retorts or from gas retorts. The commercial prospects of the manufacture in question must depend upon the possibility of profitably disposing of all the products of the coal; for (except as regards the bee-hive coke oven, which occupies a peculiar position in relation both to the coal and iron industries) the economy of carbonising coal for one, or less than the sum of all its possibilities, is doubtful.

Coal tar is an extremely curious and interesting fluid, having regard to its remarkable potentialities as the raw material of much chemical industry. To the gas manufacturer, strangely enough as it may be thought, this aspect of his tar does not specially appeal, and he reaps little or no profit from the wonderful tar derivatives which are the glory of modern chemical science. The chief fact in this connection which strikes him is, that tar fetches no more than it did before all this development of its hidden properties. It sells to as much advantage to the gas manufacturer, for making tar macadam, or tar paving, or for tarring roads to prevent dust rising from motor car traffic, as for distillation. Indeed, there are times and places when it pays better to burn it, in place of coke, for heating the retorts, than to sell. This seems a hard saying when it is remembered that the coal tar colour and drug trade of Germany, which has become the headquarters of this

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branch of chemical manufacture, employs thousands of workers and turns out millions of pounds' worth of products annually. The explanation is, that tar is made compulsorily in excess of the demand for it from this high-class chemical manufacture, which is therefore able to supply itself with its raw material on the same terms as the rest of the world. Consequently, the gas manufacturer would be as well off if he could consume his own tar in making more or better gas; which he is, therefore, always striving after.

The chemical industry of coal tar colour, scent, and drug manufacture has only a third-hand connection with town gasworks. Crude tar is usually sold off to distillers, who as a rule treat it simply for the recovery of a series of fluid distillates, and for the residual pitch, which has lately realised the best price of any of these products. A few of the largest English gasworks have tarworks of their own; but the gain thereby is not enough to tempt the majority to do likewise; which, indeed, local conditions rarely favour.

The immediate products of the distillation of tar are as follows, the sample being a typical London coal gas tar, of specific gravity 1·192 (Water = 1·000), at 60° Fahr.

	Per cent. by weight.	
Aqueous ammoniacal liquor . . .	3·53	
Light oils (distilling over before 338° F.)	1·99	Lighter than water. Include benzol, the source of aniline.
Middle oils ,, ,, 518° F.	18·46	Include naphthalene and carbolic acid.
Anthracene oils ,, above 518° F.	12·20	Source of alizarin.
Pitch (medium)	59·20	For paving, roofing, varnish, insulating, etc.
Loss	4·62	
	100·00	

A simple order of tar distilling plant, suitable for a medium size gasworks situated in a neighb

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no question of nuisance is likely to arise, would consist of a pair of pot stills of thirteen tons capacity, fed from an overhead storage tank fitted with a steam coil, to keep the tar in the best condition for the purpose. The condenser would be made up of ordinary cast iron pipes formed into a nest by bends. The collecting boxes for the runnings of the condenser would have the necessary taps for turning the successive distillates into the several storage tanks; and away from these would be the pitch cooler, followed by pitch bays, and storage yard. The still, which must only be refilled when quite cold, is fired very gradually the first day, the fires being banked up for the night, which gently warms up the whole charge; the working off of the still being completed during the following day. Immediately after the last runnings are taken off, the pitch is run out into the cooler, which is covered, and from here into the bays when cool enough.

The products of distillation, being of the various natures classified in the foregoing table, may be simply disposed of by passing the ammoniacal water into the storage tanks for the similar fluid recovered in the gas manufacture, to be treated as will shortly be described; and selling the light oils or naphtha, the heavy or creosote oil, and the pitch. It is an historical fact that tar distilling as an industry originated in the invention of Bethell, in 1838, for preserving timber, especially railway sleepers and harbour piles, by impregnating it with the heavy creosote oils distilled from gas tar. The use of the light oils for burning in "flare" lamps, as naphtha, and for dissolving indiarubber, was discovered about the same period, or earlier.

About ten years later, the interest of chemists in coal tar was shifted from the creosote to the light oils, by reason of the discovery of benzene in this portion of distillate. From benzene the step was easy to the preparation of nitro-benzene

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a substitute for oil of bitter almonds, the odour of which its own exactly resembles. In 1856 a great impulse was given to the creative, as distinct from the analytical chemistry of the coal tar compounds, by the discovery of the first of the aniline dyes, mauve, by W. H. Perkin, then a lad of eighteen. The jubilee of this remarkable discovery was celebrated throughout the world in the summer of last year (1906), when Dr. Perkin, F.R.S. (as he afterwards became), received showers of academic honours and civic distinctions for his great achievement, which was acknowledged to be the glory of English chemical science in the nineteenth century. It was more, inasmuch as it proved to be the opening up of a new industrial world. Young Perkin's personal share in this conquest was more than falls to the lot of most pioneers. "He became a manufacturer when but a youth nineteen years old, and, without ever having been inside a chemical works, he started an industry for which there were no precedents. The raw materials had to be got together, the processes of manufacture had to be devised, special apparatus had to be designed, and when the dye was made the right way of using it had to be found out" (Armstrong). Perkin earned and reaped a substantial recompense from these efforts; but when he retired from business he left no successors in England.

Much ink has been shed in controversy over the reasons why the coal tar colour and drug manufacture, thus originating in England, should have been transferred to the banks of the Rhine. This question is beyond the scope of the present book, the purpose of which is to give the facts of the industry as they exist. To return, therefore, to the treatment of the coal tar distillates, which starts with the separation, from the light oils, of the fluid hydrocarbon, benzol. It may be desirable to explain here that the nomenclature of these compounds is apt to confuse the

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uninitiated. Thus benzene, spelt with the "e," is the product characteristic of coal tar, and only found in it; whilst "benzine," spelt with an "i," comes from petroleum only. The word "benzol" is employed for the commercial mixture of benzene, toluene (a nearly allied liquid having a higher boiling point) and one or two other substances. Benzol is quoted in the chemicals market as "50" or "90 per cent.," which refers to the proportions that will distil over at under 176° and 212° Fahr. respectively, the balance being less volatile. Although chiefly obtained from coal tar, a further supply of benzol comes from the gas resulting from the manufacture of metallurgical coke in products-recovery ovens. Benzol is sometimes used in gasworks to raise the illuminating power of gas, which readily absorbs a certain percentage of it; but the economy of the device is doubtful, and it is only practicable on a comparatively small scale, which will not affect the price of the product. It has lately found a use as fuel for automobiles.

Lunge remarks of benzene that it is not merely a most important substance for industrial purposes, but even more so for theoretical chemistry. It is the origin of the enormous array of so-called aromatic compounds, the key to the composition of which is the celebrated "hexagon formula" of Kekule. Few tar distillers carry the process of obtaining commercial benzols, or the next product of the light oils, commercial toluol, farther. The remainder of the distillate at this stage is "solvent naphtha," used in the manufacture of waterproof fabrics from indiarubber; and also for dissolving grease, and cleansing clothing. A residuum may be separated as "burning naphtha," if there is a sale for it. This makes the familiar street-stall flare light.

The further rectification of commercial benzol into pure benzene and toluene is mostly done at the colour works,

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those in Germany alone being estimated to consume monthly nearly 2,000 tons of it.

The so-called "middle oils," distilling over between 338° and 518° F., contain naphthalene and carbolic acid. The former crystallises at ordinary atmospheric temperatures into white flakes which occupy a great deal of space for their weight. Some naphthalene occurs in coal gas, and is apt to cause considerable annoyance by crystallising in the mains and services, where it obstructs the flow of gas. It burns brightly, with a smoky flame, and was at one time used to brighten the light of town gas by means of the apparatus called the "albo-carbon" burner, now almost obsolete. In colour works, it is the source of a green dye, but the quantity required for this manufacture is limited. The crude carbolic acid recovered by tar distillers from their middle oils is a dirty-looking, thick fluid, which requires several redistillations to yield the pure crystals of "phenol." These do not dissolve readily in water; and the article is therefore usually prepared for the market in less pure forms. It really has a close affinity with alcohol, and is not an "acid." Its antiseptic action is chiefly exercised in preventing the development of lower organisms, which it does not actually destroy. In the living subject it coagulates albumen, corroding the skin and paralysing the nerve centres. Accidental "burns" by phenol are best treated with a fatty oil. In the pure state, phenol is employed in the manufacture of colours, and also of picric acid, used in the preparation of certain high explosives.

The fraction which distils over after the carbolic oil, at above 518° F., is a mild, greasy fluid, known as green creosote, or anthracene oil. It has been used as a lubricant, and often for burning, as its commercial value varies considerably. When the use of anthracene—which occurs in it as heavy crystals, capable of being filtered out after

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cooling—was discovered, it commanded a high price. This was because anthracene is the sole source of alizarin, which is the basis of artificial madder dye-stuff. The price soon fell, however, until in the ordinary way it scarcely pays to recover the anthracene. The reason for the commercial weakness of coal tar in this regard, as in others, lies in the compulsory nature of its origin in gas manufacture. As a mere accidental residual, its production cannot be governed

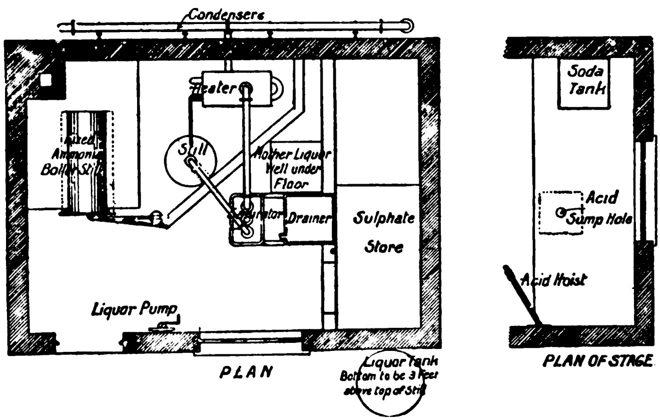

FIG. 21.—Small Sulphate of Ammonia Plant.

by reference to its market value; a circumstance of which buyers are usually able to take full advantage.

Ammonia occurs in the aqueous condensation from crude coal gas, and also in the gaseous form in the impure gas itself, from which it has to be washed out with water. A small quantity of ammoniacal water also, as already mentioned, comes over as the first distillate of coal tar. By far the largest proportion of the ammonia recovered from the coal carbonised, coked, or gasified, in the United Kingdom, is produced in town gasworks, in the marketable

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form of sulphate of ammonia. Its chief use is as a fertiliser of soils deficient of nitrogen, at one time only

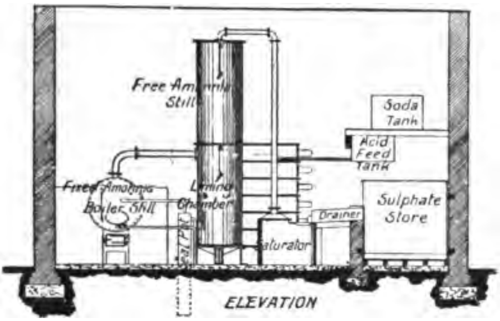

FIG. 21A.

supplied artificially in the form of farmyard manure.[1] At present, sulphate of ammonia has to compete in the market with another concentrated source of nitrogen, nitrate of soda. Its selling price accordingly varies; but it has for some years ranked next to coke as a contributory towards the reduction of the net cost of coal in gas manufacture. The production of sulphate of ammonia in British gas-works in

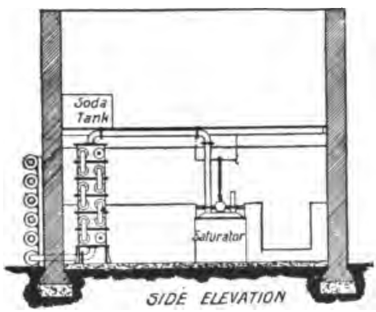

FIG. 21B.

1905 amounted to 156,000 tons, representing upwards of one-and-a-half million pounds sterling. Even so, owing

[1] Particular information relating to the qualities and application to culture on every scale, of sulphate of ammonia, is supplied gratis by the Sulphate of Ammonia Committee, 4, Fenchurch Avenue, London, E.C.

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to the exigencies of the principal manufacture—that of gas—probably less than one-half of the available ammonia of the coal is actually recovered. The process practised in gasworks for the production of sulphate of ammonia from the liquor collected in the works is simple (Figs. 21, 21A, 21B). The cold liquor is warmed by the waste steam on its way to the still, where it is heated by steam pipes for the evaporation of the "free" or uncombined portion of the ammonia, which readily comes off at 200° F. Lime is then added to the liquor, which expels the remainder of its ammonia. The gaseous ammonia is led into a "saturating" vessel, containing sulphuric acid, with which it combines to form the sulphate, in the form of a whitish powdery salt. This substance is removed from the mother liquor, and the moisture drained off. It is then fit for sale.

Sometimes the plant is so arranged as to enable the ammonia to be recovered in other forms besides the sulphate, to suit the market for the time being; as the muriate (sal ammoniac), or liquor ammoniæ, now largely used for washing, and as a refrigerant. The sulphate, however, is the product in greatest demand. Its chief use as a fertiliser is for growing sugar beet in Germany and France. Attempts to create a demand for it among British agriculturists have not met with great success; although it is appreciated by some, and the experimental farms all recommend it. Possibly the home demand for this, the strongest of nitrogenous soil-foods, may increase when the land is scientifically treated as a raw material of vegetable production, and the principles of manufacturing industry applied to this object.

Cyanogen compounds are produced in gasworks, especially where the carbonisation is carried on at a relatively high temperature. Like the ammonia, these are derived from the nitrogen originally contained in the coal; and as gas

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coals vary in their content of nitrogen, as well as in the temperature at which they are distilled, it follows that the yield of cyanides is also uncertain. Inasmuch, however, as in some works the coal carbonised is of a pretty constant character, and the retorting maintained at a regular high standard, the recovery of a cyanide as part of the purification processes can here be conveniently practised. In such cases, a proportion of cyanogen amounting to about 8 or 9 per cent. of the ammonia recovery has been reported. The method of recovering the cyanogen from the gas (in one process) is by washing at a particular stage of the purification with a solution of an iron salt, which arrests it in the form of ferrocyanide. The commercial demand for this product, which is used chiefly in the treatment of low grade gold ores, is fluctuating; and therefore the price it commands is both uncertain and not very profitable, although the temptation not to throw away any possible additional source of revenue is pressing, in view of the constantly rising labour and other expenses of gas manufacture. The limited sale for cyanide, coupled with the consideration that there are other supplies of the commodity that would be thrown on the market if inducement offered, keeps down the margin of profit in the recovery of this residual to a limit that does not encourage the multiplication of cyanide plants in British gasworks.

Sulphur is met with variously in gasworks. It occurs naturally in the coal, some descriptions containing more of the element than others, usually in the visible form of "brasses," or pyrites. No pit coal, however, is free from it. In the process of gas manufacture, some of the sulphur is distilled off with the gas, and some left behind in the coke. Of that which accompanies the gas, a portion is removed by the washing, which at the same time arrests the ammonia, and appears later in the waste gases from the

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sulphate saturator. The whole of the remainder which is in the form of sulphuretted hydrogen, is taken out of the gas, as already described, by the thorough process of dry purification to which the latter is subjected. The oxide of iron commonly employed in British gasworks for this purpose becomes so saturated with sulphur that it has a value for treatment for the recovery of this substance. Another source of sulphur is the waste gases from the sulphate of ammonia plant. In some works, this sulphuretted hydrogen is burnt in acid chambers, and oxidised to sulphuric acid for use in the same plant that it came from. Or it is burnt directly to sulphur (brimstone) in a "Claus" kiln.

The following account of the works, and list of the products manufactured at the Tar and Liquor Works of The Gas Light and Coke Company, situate at Beckton, near Woolwich, and exhibited by the Company at the International Gas Exhibition, Earl's Court, 1904, will serve as a summary of the state of the chemical industry of gas-works residuals and bye-products at this period, and their uses:

(This statement was kindly prepared for the use of the author by Mr. T. Wilton, the Manager of the Works, and is published by permission.)

The Products Works of the Gas Light and Coke Company, adjoining the Beckton Gasworks, were founded in 1879, and at the present time occupy an area of some ninety acres, and afford employment to about eight hundred men.

The whole of the tar and ammoniacal and cyanogen liquors produced in the purification of the gas at the various stations of the Company is converted into marketable products at these works. Forty-eight tar stills, each of a capacity of 2,500 gallons, are used in the initial distillation of the tar, producing the materials known as

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light oil, carbolic oil, creosote and anthracene oil, while the residue left in the still constitutes pitch, from which much of the "briquette" fuel, so largely in use on the Continent, is made. Some quantity is also used in electrical work as an insulating medium. The annual production of pitch at the works amounts to 60,000 tons. From seventeen to eighteen million gallons of tar are thus dealt with in the course of the year.

From the light oil are here recovered benzol, toluol and solvent naphtha. Benzol is the parent substance from which are derived the aniline and azo-colour industries, the well-known "magenta" (fuchsin) being one of these dyes. Toluol is also the starting point for some valuable coal-tar colours, artificial indigo being formerly made from this product. It also is a most useful solvent, and is employed in the manufacture of xylonite. That wonderful substance saccharin, which is three hundred times sweeter than cane-sugar, and has largely supplanted the latter for some purposes, is manufactured from toluol. Creosote is still the most valuable preservative for timber, and from it and the carbolic oil are obtained naphthalene and carbolic acid. Apart from the well-known use of the latter product as an antiseptic, it is a starting point for a further series of important dye-stuffs. Lyddite (picric acid), is made from the pure crystal carbolic acid.

Naphthalene is made in various forms, such as "Flake," "Tablet," "Candle," "Balls," "Powder," "Rice," etc., suitable for its various and important uses. As a moth preventive it is known to everyone, but few people, perhaps, are aware that artificial indigo is now made from this substance, besides other valuable colours. From anthracene oil are obtained anthracene, from which is made alizarine (Turkey-red), and a number of madder dye-stuffs. A valuable lubricant is also made from this oil.

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The refined tar is used for tarring rough woodwork and iron structures and for the manufacture of roofing felts. It is used with road metal for making a dustless and excellent covering for roads.

Other bye-products obtained from the tar are a disinfectant known as "Bectol"; pyridine, which is largely used for denaturising alcohol, and is also used in the manufacture of certain dye-stuffs; and soluble creosote, a valuable disinfectant largely used with sheep dip.

At the ammonia works of the company 54 million gallons of ammoniacal liquor are treated every year. From it are made 16,000 to 17,000 tons of ammonium sulphate per annum.

Muriate of ammonia is also made from this liquor, some 200 tons per annum being manufactured for the use of galvanisers and calico printers, and also for charging galvanic batteries. Nearly 500 tons of liquid ammonia of various strengths, and 150 tons of anhydrous ammonia are manufactured each year from the gas liquor. The former is used for cleansing and other purposes, and the latter, which is the liquefied gas, and is sold in steel bottles under considerable pressure, is largely used in refrigerating machines. Nitrate of ammonia is also made from the ammoniacal liquor. It is the important constituent of the modern "amide" gunpowders, and is used in the manufacture of explosives and also for the preparation of nitrous oxide (laughing gas), used so largely in dentistry and surgery.

The extensive sulphuric acid plant which is necessary for the manufacture of the ammonium sulphate is capable of producing 25,000 tons of acid per annum.

From the cyanogen liquor are produced cyanides of sodium and potassium of great purity, also Prussian blue; besides a large quantity of the prussiates of soda and

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potash. The cyanide is also employed in the electro-plating industry, and in photography; and is one of the most deadly poisons known to science.

The Prussian blue is made in a number of grades and tints ranging from an exquisite bronze to a deep indigo blue. It is used in the manufacture of fine printing inks, and also for paper staining.

List of Beckton Tar Products (1904).

Solvent Naphtha.—Used in the manufacture of waterproof fabrics, and solvent for indiarubber.

Pure Benzol.—A solvent for waxes, fats, sulphur, phosphorus, iodine, and gutta percha. Manufacture of aniline dyes.

Pure Tuluol.—Partly a solvent; also used in the manufacture of aniline dyes.

Benzol, 90 *per cent.*—A solvent for waxes, fats, etc.

Sharp Oil.—Lampblack and soluble creosote manufacture, and also used as fuel.

Creosote, Liquid.—Lighting, fuel, and manufacture of soluble creosote.

Creosote, Ordinary.—Manufacture of naphthalene, and pickling timber.

Creosote Salts.—Manufacture of pure naphthaline.

Naphthalene, Various Forms.—Manufacture of dye-stuffs, preserving skins, furs, etc. Also moth preventive.

Carbolic Miscible, A.—Disinfectant.

Carbolic Miscible, B.—Disinfectant.

Creosote, Soluble, Special.—Cleaning and disinfecting (for cold climates), sheep dip.

Bectol.—Disinfectant.

Carbolic Acid, Crude.—Disinfectant; also used in the preparation of picric acid.

Sodium Cyanide.—Gold extracting and silver plating.

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Cyanogen, Purple.—Pigment.

Hatchet Brown, Light Shade.—Largely used in artistic and mural decorative work.

Hatchet Brown, Dark Shade.—Largely used in artistic and mural decorative work.

Various Preparations of Prussian Blue.—Used for printing inks.

Cyanogen Purple Solution.—A new pigment.

Sulphur.—Manufacture of sulphuric acid.

Iron Oxide.—Manufacture of paint.

Oxide Paint.—Preserving iron work.

Liquid Carbolic Acid.—Preparation of soluble creosote, sheep dip, etc.

Carbolic Acid, Detached Crystals.—Antiseptic.

Carbolic Acid, Liquefied Crystals.—Antiseptic.

Carbolic Acid, Crystals, 39-40 *per cent.*—Preparation of picric acid; also used in the manufacture of salicylic acid and soap.

Carbazol.—Dyes.

Green Oil.—Constituent of wagon grease, and also used as a fuel.

Anthracene Oil.—Manufacture of anthracene.

Anthracene, 40 *per cent.*—Manufacture of alizarin.

Anthracene, 80 *per cent.*—Manufacture of alizarin.

Anthracene, 90 *per cent.*—Manufacture of alizarin.

Anthraquinone.—Manufacture of alizarin.

Alizarin.—Alizarin dyes.

Crude Bases.—Preparation of pyridine, lutidines, etc.

Pyridine.—Principally for denaturising alcohol.

Nitro-Benzol.—Production of aniline; sometimes used as a perfume.

Aniline.—Aniline dyes.

Pitch.—Briquettes for fuel, and asphalt; also for electrical work.

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Refined Tar.—Tarring rough woodwork, roofing felts, and for asphalt.

Creosote, Soluble, No. 1.—Cleaning and disinfecting, sheep dip.

Ammoniacal Liquor Products.

Ammoniacal Liquor.—Preparation of liquid and anhydrous ammonia, also ammoniacal salts.

Ammonia, Liquid, Sp. Gr. ·880.—Preparation of ammonia salts, toilet and cleaning purposes.

Ammonium Carbonate.—For smelling salts, etc.

Ammonium Chloride (Muriate) Crystals, Refined White.—Galvanising and calico printing.

Ammonium Chloride (Muriate) (Dog's Tooth Crystals).—Galvanising and calico printing.

Ammonium Chloride (Muriate) (Ordinary).—Battery purposes, galvanising, etc.

Ammonium Sulphate.—This salt is a constituent of artificial manures, and is also largely used in the preparation of liquid ammonia, alum, and in the ammonia soda process.

Ammonium Nitrate.—Much used in the preparation of nitrous oxide gas and explosives.

Anhydrous Ammonia, Cylinder and Case.—Refrigerating purposes.

Cyanogen Liquor Products.

Cyanogen Liquor.—Preparation of Prussian blues.

Prussiate of Potash, Yellow.—Manufacture of Prussian blue and potassium cyanide.

Prussiate of Soda, Yellow.—Manufacture of Prussian blue and sodium cyanide.

Red Prussiate of Potash.

Potassium Cyanide.—Gold extracting and silver plating.

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It will appear from the foregoing account of the multifarious activities of the residuals department of a modern gasworks, that nothing extracted from the raw material, coal, is lost sight of or permitted to escape, if it is worth saving for the market. Two of these bye-products, coke and tar, may be described as having always had their obvious uses, and corresponding money values. In the case of the other bye-products now brought into the revenue accounts of a town gasworks, they long remained in the category of "impurities" which had to be got rid of somehow, before their proper uses were found and their market values determined. If the economy of the gasworks treatment of coal is contrasted with the wastefulness of burning it directly by means of a fire-grate, industrial or domestic, for its sensible heat of combustion alone—every other comcomitant of this proceeding being disregarded or permitted to constitute a nuisance—the conclusion that must be drawn is that the former is by far the preferable method of treating the national coal capital, or at least so much of it as is suitable for the purpose.

It is quite true, although the fact is not always understood or viewed in the light of all the circumstances and conditions, that in some places and at times the residual products of coal gas manufacture bring in enough money to pay the prime cost of the coal. It is, however, absurd to deduce from this accidental circumstance, as is sometimes done by non-technical persons, that therefore the gas costs nothing, and might be given away in these cases. Apart altogether from the profound economic truth that nothing can be had for nothing, in town gas manufacture the net cost of the raw material forms only one element of the total cost of the supply, and never a preponderant one. In the public service of town's water supply, with which gas supply has so much in common that the law

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of one is often the law of the other, the raw material never costs anything, yet the distributed supply often costs a good deal. The economic weakness of the whole gas residuals trade, from the sellers' point of view, proceeds from the fundamental condition, perfectly well known to the prospective buyer, that the volume of the production is not under control. The manufacture, whether of coke, tar, or sulphate of ammonia, must follow the demand for gas, whatever the state of the respective markets. It is this helplessness of the producer in their regard which distinguishes bye-products or residuals from the staple article of his trade. The distinction is sometimes lost sight of in amateur discussions of matters of industrial economics, so that one hears talk of prospects of making the largest profit out of bye-products; or by the working-up of waste products which are to be had for next to nothing.

It is the absence of any economic relation between the value of the chief product, for which the concern has to be carried on at all hazards, and of the accidental bye-products or residuals, which is fatal to schemes of the former variety. The demand for town gas must be met, whatever the cost of the raw materials used in the manufacture. The price of gas coal is governed by other influences than the demand for gas—which varies little—usually by the state of the iron, engineering, and shipping trades, and by colliers' wages. When these trades are brisk, so that their demands for fuel are large and increasing, gas coals rise in price, gas oil becomes dearer in sympathy, and the cost of gas manufacture is disproportionately greater; because it by no means follows that the market for residuals moves in the same sense. The economic doctrine of "equivalent values," in virtue of which all possible substitutes for a commodity participate in its enhancement or depression, hits the gas manufacturer in his oil supply, as already

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remarked, whenever his coal goes up; but the coke he has to dispose of is not such an exact substitute for coal that he can always depend upon obtaining an equivalent price for it. And tar and sulphate of ammonia are never affected by the cost of the coal from which they are produced.

Therefore, in town gas manufacture, it is rarely possible to "get back by the swings what is lost on the roundabouts," as the doctrine of economic variations is succinctly expressed in the terse language of the showman. Coal may cost a gas company 3*s*. or 4*s*. per ton more this year than last; but the coke may not fetch more than a few pence per ton in advance of the old price, whilst tar and ammonia may even fall. It is impossible to rely upon the bye-products for a permanent ratio of return on the cost of coal. When they do happen to sell well, the best course to follow is to let them go, and put the money by in the shape of reserve fund against the inevitable rainy day.

With regard to the other economic delusion, that abnormal profits are to be made by working up waste material that can be had originally for nothing, whether for gas manufacture or any other purpose, those who entertain it only do so by ignoring the "principle of rent." They forget the landlord, or "reckon without their host." It may be, and often is, possible to pick up something which other people have no use for, or have thrown aside, and turn it to account. There is commonly a drawback to the proceeding, which must always be of an accidental and limited validity. If one could only go to the pit's mouth, where oven coke is made from the small coal, one might apparently have a good deal of excellent gas, the waste of the ovens, for nothing. But this condition would only endure for so long as nobody really wants the gas that is wasted. If it were seriously proposed to lay down works for taking advantage of this gas, the owner would

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immediately put a price upon it. This operation has been exhibited time after time in connection with all kinds of commodities; and yet there are to be found people who delude themselves and others that the principle can be overlooked. There are a few small gas undertakings in different parts of the country, which are able to obtain the supplies of high-class coal they require at remarkably low cost, because the large works are not in the market for the same raw material. The same fortunate works may happen also to be favourably situated for disposing of their residuals locally at good prices; but no argument can be founded on such facts, respecting the possibilities of other undertakings which must be carried on elsewhere under their own peculiar conditions.

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CHAPTER IV.

GAS LIGHTS AND LIGHTING.

Original object of coal gas manufacture—Self-luminous burners—Regenerative gas lamps—The invention of the incandescent gas light—Its struggles and triumph—Its effect upon the policy of gas companies—Description of the system—Details of the burner—Fundamental principles—The "Kern" burner—Other upright incandescent gas burners—Inverted incandescent gas lamps—Wide range of incandescent gas lights—Self-intensifying lamps—High-pressure lamps—Descriptions of various systems in use—Possible developments.

THE purpose for which coal gas was originally made and used, was that of giving light by its flame. Gas being self-luminous, this is a very simple matter, as the gas must show a light when burnt in air. It was very early observed, however, that the design and construction of the "burner"—meaning the modified termination of the gas supply pipe from which the flame starts, and sometimes the dispositions made for the access of the necessary quantity of air for combustion, including the chimney—exercised a great influence upon the luminosity of the gas. Thus the practical value of any sample of town gas as an illuminant has never been regarded as a fixed quantity inherent in the gas; but always with reference to the particular burner employed. This aspect of gas light, so far as is necessary to explain the selection of standard test burners and the rating of the gas in terms of statutory illuminating pow[illegible] is sufficiently discussed in Chapter I. So early [illegible] [illegible]y of the gas industry as 1815, the advant[illegible]

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Argand type of burner for developing the luminosity of common coal gas were recognised, so far as it lent itself to the regulation of the air supply. But the very fact of burners of this type owing their virtue to carefully-proportioned air currents means that they are too sensitive to draughts for general use. Consequently, for this reason, and also on account of their cost and the trouble of keeping the chimneys clean, Argand burners never suited the mass of

FIG. 22.—Improved flat-flame burners.

gas consumers; but were confined to the dignified and quiet atmosphere of banks, libraries, etc.

The common run of gas lights, alike for private use and in public street lamps, was made up of various patterns of flat-flame burners, without exception of low efficiency as light yielders. They were called batwing, union-jet, or fishtail burners, from the shape of the flame of the burning gas. They were made of metal, the first like a small thimble with a saw-cut across the top, the latter of similar construction, only with two round holes pierced in the top, looking towards one another nearly at a right angle. The effect of this disposition was that the two issuing gas jets met and flattened one another out into [illegible] joint fan-shaped flame, which [illegible] the [illegible] batwing, and

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was therefore more suitable for glass globular shades. Down to the present time there exists no other pattern of flat-flame gas burners; but their efficiency has been greatly improved, chiefly by making the actual burner tip of steatite or porcelain, which preserves the shape and size of the slit or holes better than metal, and, being a non-conductor of heat, also keeps the flame hotter, and consequently brighter (Fig. 22).

A marked improvement in flat-flame burners and their economy, was brought about some years back by the introduction of regulators, or governors, of the gas pressure at the point of combustion. All luminous flame burners do best at a low pressure and a uniform one (say five-tenths of an inch of water). When such burners sing, roar, and flare in ragged points, too much gas is passing, and not giving its proper light. As it is practically impossible to check excessive pressure and consumption in the case of domestic flat flames by the burner tap, and quite impossible in the case of public street lamps, this object is attained by making the gas pass through a little appliance in which excessive pressure lifts a valve which chokes the supply, restoring it as the pressure falls. Or the same effect is obtained well enough for most practical purposes, by putting a Bray's "economiser" of a higher number, upon a Bray's burner—as, for example, a No. 7 "economiser" on a No. 4 regulator burner. This arrangement is effective in dealing with the increased main pressures usual at the present time.

Flat-flame burners still have their uses for particular purposes and in certain situations. They are all that is required when the object is merely to "show a ligh... they will withstand rough usage. For safety li... cellars, corridors, and public stairways they are ... as they do not need any attention. They a... however, for every purpose of public a...

in which either brilliancy of luminous effect or saving of gas is a consideration; as gas lighting by incandescence (Welsbach's system) is at least ten times more efficient, with a far greater range of power. Just before the Welsbach invention appeared, there was a brief era in the development of gas light in which what were known favourably as the "regenerative" lamps of F. Siemens, Wenham, Grimston, and Bower figured conspicuously. In this system of using gas for lighting, the self-luminous flame was employed, supplied with heated air, which materially enhanced its brilliancy. All these lamps worked on a closed cycle of heat exchanges, in which the hot products of combustion imparted some of their heat to the inflowing air and gas. Their efficiency was three or four times that of the ordinary flat-flame burners; but they were costly, and required careful adjustment and looking after. Their greatest recommendation was that they lent themselves readily to assist the general ventilation of interiors, for which purpose they are still retained in some smoking-rooms, etc. They can usually be refitted to advantage for the incandescent system.

Actual modern gas light dates from the invention, in 1885, by Carl, Ritter von Welsbach, an Austrian chemist of repute in the higher walks of metallurgy, of "an illuminant appliance," to quote the specification of the famous master patent, "consisting of a cap or hood" of textile fabric, which, having been steeped in a solution of the nitrates of the so-called "rare earths," thoria and ceria, was to be suspended over a bunsen (atmospheric or non-luminous) gas flame. Hereupon the substance composing the fabric would burn away, leaving a skeleton of its form consisting of the oxides of the rare earths in question, which, being very refractory, would be raised to brilliantly luminous incandescence by the heat of the burning gas. The

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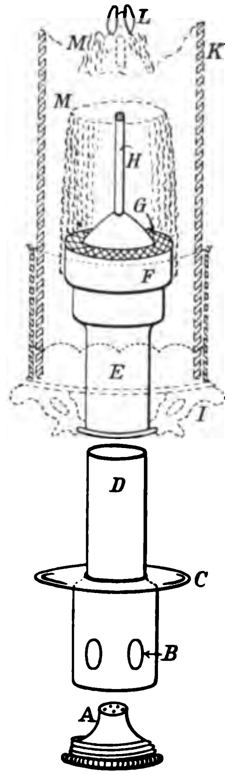

FIG. 23.—Diagrammatic drawing of a Welsbach "C" burner.

A, Gas injection nipple, screwed to take D; B, Air inlets; C, Guard plate, to prevent the flash when burner is lighted from entering B and igniting the gas at the nipple; D, the shaft of the burner, in which the gas and air mix; E, the burner top, sliding over D, and carrying the gallery I, which holds the glass chimney K; F, the burner head, expanded to fit the mantle, and ending in the wire gauze top G, and the socket for the rod H supporting the mantle MM; L, crutch top of the mantle rod, taking the asbestos loop of the mantle.

invention had a weak and perilous infancy. Much mystery wrapped its earliest appearances in Vienna, and no experienced firm of gas lighting engineers anywhere would touch

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it. How it eventually struggled through the inevitable trials of new and great inventions would take a volume to narrate in detail. It has been truly said that the critical stages of the development of all true inventions are the same. First, the knowing ones declare it is of no use; next, that it is not practical; lastly, that there is no novelty in it, and it is not the property of the inventor and patentee —in short, that everybody knew about it all along!

All this, and more, was adduced against von Welsbach's invention, which was not only hampered by the imperfections of youth, but was also prejudiced by the fact of its dependence upon the properties of certain natural mineral elements, previously of the rarest occurrence, and only mentioned in the extant text-books as curiosities of mineralogy. Driven back upon their own resources by the coldness of all expert opinion, von Welsbach and his associates had to attack the problem of the supply of the raw material necessary to their manufacture; and were rewarded by the discovery that the scarcity of these minerals was not positive, but merely temporary, and that they exist in various localities in adequate quantity. They also worked out the method of applying the illuminant elements to the best advantage, so that the formula they arrived at for the dipping solution (thoria, 99 per cent.; ceria, 1 per cent.) has held good ever since. Another grave objection to the system was, and still is, the fragility of the illuminant body, which came to be called the "mantle." This weakness the original exploiters of the invention only partially cured by adopting a treatment of the mantles by varnishing, which enables them to be handled and transmitted in packing-cases (Fig. 23).

During the several years after the success of the system became assured, and its universal adoption by gas consumers was perceived to be only a question of price and

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time, the gas companies were feeling their way to officially adopting it, in the sense of carrying out public and private installations of the system. Although the public were taking very kindly to the new fashion of gas light, the difficulty of the fragility of the mantles, and of the necessity of paying more attention to the condition of the burners and chimneys than gas consumers were accustomed to bestow upon the lights these displaced, finally constrained the gas companies to come to the rescue by offering not merely to instal, but thereafter to maintain at a nominal charge, the system in good and satisfactory condition. This was a notable new departure and altogether fresh responsibility for the gas companies; who had previously regarded their duty to the consumer as ending with the supply of gas at his meter. In effect, it has entailed almost everywhere the setting up by the gas companies of a complete gas appliance and fittings department of their undertaking, to the great gain and convenience of the public generally.

As actually used, to the supersession of all other methods of gas lighting, the Welsbach system falls normally into three main divisions of appliances. These are—

(1) Upright burners; with normal gas and air supply.
(2) Inverted burners; ,, ,, ,,
(3) Burners with increased pressure gas or air supply.

There is no patent in a bunsen burner, and the market is supplied with a choice of such burners well adapted to light up the stock "C" size mantle, of which there are also many makes. In regard to these goods, the purchaser has only to be guided in his selection by the old and sound rule that one pays a little more for a better article, and gets more satisfaction from it in the end. The particular size of mantle in question should yield with any town gas a light of at least 80 candle power, measured in the horizontal

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direction, for a consumption of from 3½ to 4 cubic feet per hour. That is to say, the "efficiency" (hereinafter expressed by the letter E) in candle power per cubic foot of hourly gas consumption, may be reasonably expected to be from 18 to 20 candles, with common town gas rated as of 14 candle power. Even cheap mantles and burners of this size will do as much for a time; but they are not so stout nor so durable as the better class of goods. It is advisable to make this remark, because some people who have reasons of their own for depreciating incandescent gas-light, commonly allege that it exhibits rapid falling off from the efficiency of new mantles. Certainly, there are mantles which are of little or no use after 200 hours or so; but it is not necessary to buy them. Good mantles, upright or inverted, will last many months in the ordinary way.

Mantles, of whatever size, and howsoever named, are in the vast majority of examples made precisely alike, of the fibre of "ramie," or Indian hemp, dipped in the Welsbach standard solution of thoria, 99 per cent.; ceria, 1 per cent. Ramie is the chosen textile material for the weaving of mantles; because it leaves less ash on burning, and shrinks less, than any other known. Some fabrics are composed of artificial silk. Of the dipping solution, the thoria is for strength, and all the light comes from the microscopic proportion of ceria, the remarkable fact in this regard being that no other proportion of the active ingredient will serve. The better mantles have a heavier loading of the minerals, but this cannot be carried too far. The chief raw material from which these once rare earths is derived, is a heavy sand known as "monazite," occurring on the coast of Brazil, and in a few other localities, in workable quantity. The elements themselves are found in inconsiderable traces in many igneous rocks. The true cause of their luminescence in the gas mantle has been

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much debated; but it is now agreed to be chiefly an effect of temperature. They do not melt at the highest temperature of the flame of town gas burnt with air, which has never been satisfactorily measured, but is certainly above the melting point of platinum (1,760° C.) The shape of the mantle, moreover, is fitted to that of the outside film of the conical bunsen gas flame, where it is hottest. The skeleton frame of the mantle helps to preserve the position of this hottest part of the flame; and thus the mantle and the gas lend one another mutual assistance. The upright mantles are provided at the head with a loop of asbestos thread for dropping into the crutched top of the mantle rod of the burner. In putting on a new mantle, it should be handled gently by this head, and then ignited at the top to burn off the collodion varnish. Some makes of mantles are flexible, without stiffening. It should then be observed that the skeleton (which must not be touched again) hangs centrally with and loosely fits the burner head; when it will yield its proper effect, with suitable gas pressure.

Incandescent burners require for their best performance a gas pressure of not less than 1½ inches (15-tenths) of water. Thus, as compared with luminous flame burners, the system may be distinguished as a normally high-pressure one; which fact is now fully understood by gas companies, who have increased their main pressures accordingly. The gas pressures must not, however, be excessive. When the limit of 25-tenths is exceeded, the use of a regulator or governor becomes advisable. This observation does not apply to incandescent burners belonging to the "high pressure" class to be described in due course.

The quality of the mantle being determined as described, by its composition, the attention of inventors desirous of still further improving the luminous efficiency of the system

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was perforce concentrated upon the other member of the combination known as the "Welsbach light"—namely, the bunsen burner. von Welsbach had at first to take the bunsen or atmospheric gas burner as he found it ready to his hand. His assistant-mechanics merely adapted the ordinary laboratory bunsen to the novel purpose, and never suspected that it was susceptible of improvement.

The air mixed with the gas before ignition in such a burner is sometimes called the "primary" air, to distinguish it from the further supply of air freely flowing to and completing the combustion of the flame at the burner head, which is then called the "secondary" air.

It has been stated, with the analysis of different combustible gases given in Chapter I., how much air each requires for its complete combustion. When such gases are burnt without the previous admixture of any air, their flames help themselves to as much air as they require from the surrounding atmosphere; but if there is any such previous admixture, clearly so much less is required for the second, or final aeration and combustion.

Thus, for example, a sample of town gas needs five-and-a-quarter times its own bulk of air for complete combustion. It will take the same quantity, whether the luminous flame is burnt in the air, or whether it is bunsenized, or exploded all at once. Another feature of the operation is that the size of the gas flame depends upon the quantity of air it has to pick up. The luminous flame of this particular sample of gas, burning at the rate of, say, 5 cubic feet an hour, presents to the atmosphere an absorbent surface precisely large enough for its purpose. If this gas is caused to mix in a bunsen burner with, say one-half of the air it needs in burning, the flame will only want the other half. It will be correspondingly smaller. It is quite easy to obtain this mixture in an ordinary laboratory bunsen burner. The flame will

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be blue, quiet, rather languid; and this was the kind of flame with which the early Welsbach burners worked. If more air, say 3 volumes, is admitted to the bunsen, the flame becomes altered in character. It is shortened, becomes more intense, showing a green colour where the primary air burns inside. If still more air, say, from 3½ to 4 volumes, is admitted to a bunsen of ordinary construction, the flame will "light back" at the jet.


FIG. 24.

Evidently, from all this, the more primary air a burner can be made to carry, the more intense will be the combustion; and this is so. Ability to carry more air is, in a bunsen, a question of better commixture of the air and gas, and of prevention of firing back. The more complete the mixture, the smaller the risk of any small eddy of over-aerated gas lighting explosively, and so firing the incoming gas at the nipple, and the more uniform will be the secondary ignition. With a mixture poorer than 1 of gas to 3½ of air, it is necessary to provide the burner head with a diaphragm of wire gauze or an equivalent (on the principle of the Davy safety lamp) to prevent the whole from firing back.

A successful improvement upon the plain bunsen burner of the "C" type, embodying these principles, was made in the "Kern" burner (Fig. 24). It will be noticed that in this burner the shaft is considerably lengthened; and its shape is also altered from a cylinder to that of double truncated

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cones, of different tapers. This is an ancient device, known to the Romans, for increasing the flow of a fluid through a pipe with a fixed maximum bore. In the present application it increases the proportion of air which a gas jet of given rate of discharge can entrain. The upper end of the burner shaft is also formed into a mixing chamber, and the burner head is fitted with a peculiar arrangement for breaking up the primary combustion into numerous little flames, and sending the secondary flame with a swirling motion towards the outside, where the mantle comes in contact with it. The net result of these modifications of the cylindrical bunsen is that the mantle yields on the average 25 per cent. more light for the gas consumed. That is to say, with the "Kern" burner, E = 25 candle power per cubic foot of gas consumed per hour. It requires no chimney.

FIG. 25.—"Bray" incandescent burner, with by-pass and pilot light.

"Kern" burners are graded by numbers corresponding with their consumption of ordinary town gas at a pressure of 10-tenths, or 1 inch of water column. Thus, Nos. 1, 2, 3, or 4 "Kerns" will burn so many cubic feet of gas per hour, always, if in good order, at the efficiency above stated; for it is one of the claims for this burner, that the smaller ones are as good

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proportionately as the large sizes. No. 2, yielding a light of 50 candle power, or No. 3, is the usual domestic size.

FIG. 26.

No. 4 is chiefly used for public street lights, yielding a light of 100 candle power.

It is quite unnecessary to discuss many other commercial patterns of upright incandescent gas burners of equal power, as these, although numerous, are only variants of the Welsbach "C" and "Kern" types, depending for their popularity upon details of construction, which in some instances are [illegible].

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A distinct form of upright incandescent burner is the "Bray" (Fig. 25), in which there is an arrangement for adjusting the quantity of gas and air to suit varying composition of the former. It also has a durable cap of refractory substance in contact with the flame; and possesses the great merit of practically never "lighting back" when the gas is lowered. Another pattern of burner possessing distinct features of merit is the "Sugg" (Fig. 26), which also has a pierced steatite top, and is adapted to dispense with a chimney, thus lending itself to the well-known "Christiania" principle of domestic lighting by the same inventor (originally applied to flat-flame lighting) in which a particularly graceful and efficient type of downward-reflecting opalescent globes is an important element. All these various burners can be had with "pilot" lights, which dispense with matches or tapers for lighting, and are capable of being controlled from a distance, so as to light or extinguish the burner by the movement of a wall-push, or switch.

No upright incandescent burner should ever be used without a proper shade, or reflector, for indoor lighting, as it yields the larger proportion of its luminous effect in an upward direction, and is not shadowless; as will be explained fully in the next chapter.

Inverted Incandescent Gas Lamps.—The upright type of incandescent gas burner had barely attested its immense economic superiority to every other known artificial illuminant of the same order of brilliancy, when its popularity with private consumers of gas was challenged by an inverted style of the same principle of lighting. The upright incandescent lights belonged obviously to the same class of fittings as the familiar argands and flat-flames which they displaced. Indeed, except in their whiteness and greater luminosity, the new gas lights differed little from the old

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in aspect. There was the same rigidity of fixture; and the higher intensity of the incandescent light accentuated the fact that it had an unequal distribution. Its supports cast

FIG. 27.—The "New Inverted" lamp; gas consumption $3\frac{1}{4}$ cubic feet per hour.

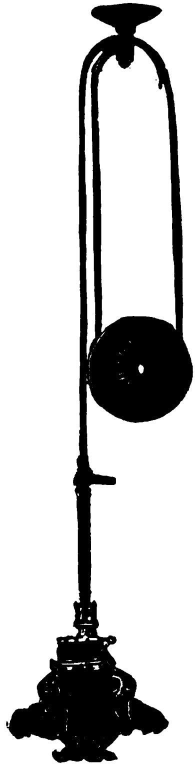

FIG. 28.—Inverted lamp and "Hanwell" pendant, for dining rooms, etc.

a shadow downwards. People who previously felt no particular admiration for gaslight and its usual embodiments, were no more attracted aesthetically by the upright incandescent mantle, though they might make use of it and

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appreciate its economy. The inverted incandescent light, however, which was little known before the Earl's Court Gas Exhibition of 1904, there and then took the town by storm. The tiny bulbs, with inverted mantles no bigger than a lady's thimble, each giving a light of 20 candle power for a consumption of 1 cubic foot of gas per hour, were seen to be amenable to artistic treatment. The larger-sized lamps, burning 3 cubic feet an hour, hung gracefully from curving arms, or depended from flexible tube connections. The light was shadowless, and shone brightest in the downward direction. Nothing like it had ever been seen, except the incandescent electric light. The efficiency of the new lamps, moreover, was excellent, quite equalling that of the Welsbach "C" burners—namely, E = 20 candles per cubic foot of hourly gas consumption.

Fig. 29.—Wall bracket, with pair of bijou inverted burners; gas consumption 1 cubic foot per hour each.

The usual full size inverted lamp burns 3 to 3½ cubic feet of gas per hour at a pressure of from $\frac{15}{10}$ in. to $\frac{20}{10}$ in. The mantles last remarkably well, owing to the more favourable method of suspension—from the largest part, instead of the smallest; and away from the cutting action of the flame. So marked is this, that the principle succeeds admirably for lighting railway carriages, despite the oscillation; to which use it is largely applied.

All inverted gas burners can also be had fitted with "pilot" lights if desired.

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It will be understood from what has been written, that gaslight can be had with equal convenience and strictly proportionate economy, of any desired intensity up to 100 candle power, with a single burner. Double, treble, quadruple, and quintuple groupings of the largest single burners offer a simple and effective means of increasing the volume of light radiated from a single point, to the highest intensity ever required, except in special cases. It may therefore be said that the requirements of any user of artificial light for every indoor or outdoor application up to 500 candle power units, can be satisfied with town gas, drawn from the street mains in the ordinary way (Fig. 30).

For lights of still higher intensity, the principle of high-pressure incandescent gas lighting is applicable, with material economy of gas per candle power. This principle is found suitable either for providing a service of high-power lights, such as are in favour for the lighting of large open spaces, wide thoroughfares, the frontages of important public buildings, railway stations, goods-yards, docks, commercial emporiums, etc., or for the effective distributed lighting by small units of clothing and boot factories, in order to conquer the dinginess of the materials handled. In the former applications of the high pressure method, the normal illuminative unit is 600 candle power, although arrangements are common for modifying the intensity of the street lamps after certain hours, or when the full brilliancy is not wanted. Single light sources of above 1,000 candle power are seldom called for; except in the case of lighthouses, for which high pressure gas is being largely adopted.

Where one or two powerful lights only are required (as at street crossing refuges, or for the purpose of attracting notice to a place of business) self-acting mechanically pressure-increasing lamps, as the "Scott-Snell," can be

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recommended. These are of 600 candle power, and have a mean efficiency of 30 candles per cubic foot of hourly consumption; or E = 30. Comparing this with the efficiency of the ordinary pressure "Kern" burner, 25 candles

FIG 30.— High-power lamp; normal gas pressures.

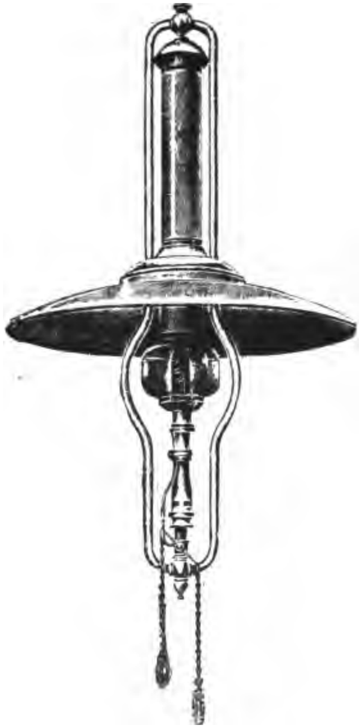

FIG. 31.—Self-intensifying lamp (Welsbach-Kern).

per cubic foot, it will be seen that the higher gas pressure represents a material gain of efficiency, which in these cases is also economy. For it is not necessary to burn any particular quantity of gas in order to realise all the economy of the high pressure principle in incandescent

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gas lighting; but the consumer can take the advantage in either way, by obtaining more light from his gas, or getting the same amount of light from a reduced consumption.

Other forms of self-intensifying high-power lamps are the "Welsbach-Kern" make, by this name (Fig. 31), and the "Lucas." This class of lamps works upon the principle of increasing the injection effect in the bunsen, by adding the pull of a sharp chimney-draught to the pressure of the gas upon the air. The result is the same as though the gas pressure were equivalently heightened—that is to say, it increases the proportion of primary air taken into the burner, thereby intensifying the secondary combustion, which, in turn, makes a brighter light. The uncertainty of chimney draught is the chief drawback to this method of working; but the light is very fine, and self-contained lamps are convenient, and not expensive.

Of course, the most trustworthy systems of high-power lighting are those in which mechanical power is applied to produce the increased gas pressure. Like everything else connected with the industry, this principle of lighting has passed through many phases and vicissitudes before emerging in the simple embodiments now in use. The earlier attempts were encumbered with complications, which had to be proved superfluous before the simpler forms of apparatus could be decided upon. Moreover, the precise applications most suited to the principle could not be foreseen; neither was the secret of its actual operation known. As already partly explained, with respect to the *modus operandi* of self-intensifying lamps with the chimney effect, intensification of the burner action is a matter entirely of gas injection and the consequent air entraining effect. The actual flame of a burner working under the highest gas (or air) pressure has not in itself any increase

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of pressure measurable by the most delicate gauges. Thus the flame which heats the mantle is not a blow-pipe flame. The question that may be asked in this regard is, naturally "Then what does the increased gas pressure do; and what

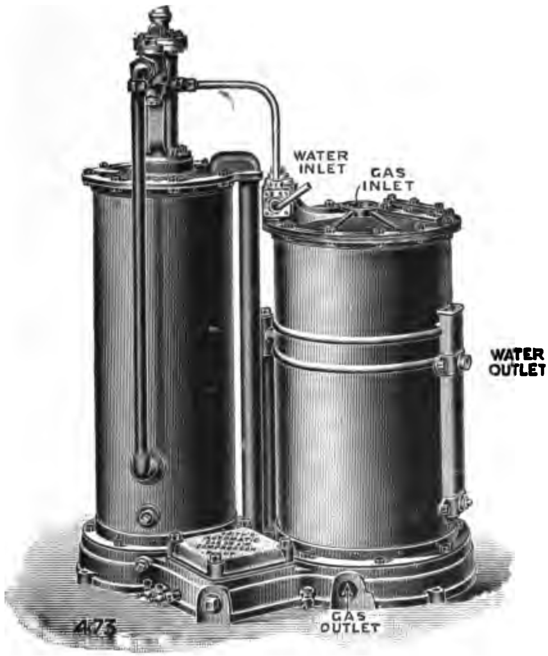

FIG. 32.

becomes of it?" It is translated at the outlet of the injector nipple into energy of motion, at a correspondingly high velocity. Therefore, it is able to do more work upon the air, quickly overcoming its inertia, dragging it forward and up to the point of ignition in larger proportion and at a greater speed than is possible with normal gas main pressures.

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The practical embodiment of this principle starts at a mean gas pressure increased to 9 inches of water; prefer-

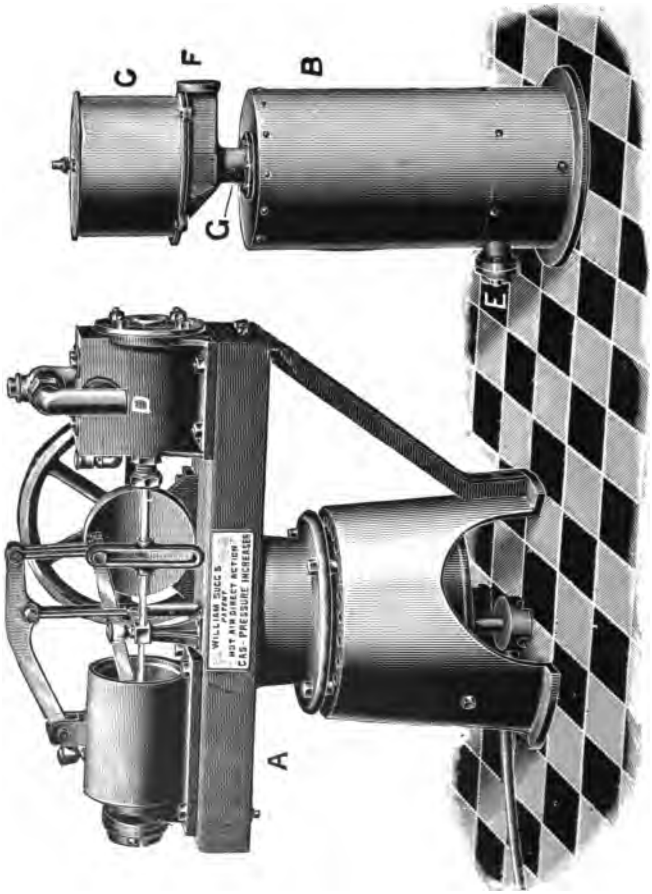

Fig. 33.—"Sugg" Pressure-Increasing Plant. A, Hot-air engine; D, Gas-pump; B and C, Gas reservoir and governor; E, F, G, Gas connections.

ably by water power where this is available, applied by a very simple, compact, and inexpensive apparatus. This is known as the "Keith" system (Fig. 32). It is equally

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suitable for high-power lamps, or for the smallest inverted burners, of which admirable use can be made in clothing factories, or by watchmakers, etc.—wherever, in short, a strong, steady light, without glare, is wanted in close proximity to the work and the worker. The normal efficiency of the system is 30 candle power per cubic foot of gas ($E = 30$); and is the same with the small inverted burners, consuming only 1 cubic foot per hour, as in the big lanterns. An incidental recommendation of this system for factories, reading rooms, composing rooms, etc., is that the very small gas consumption puts no appreciably greater strain upon the ventilation of the place. The small water power required to work the "Keith" system can be taken cheaply from the town mains; or other power can be substituted for it. In London the water required costs 1*d.* per 1,000 cubic feet of gas treated.

Another system of increased gas pressure lighting is the "Sugg," which is normally done at 15 inches of water pressure (Fig. 33). This arrangement is preferably worked by a small gas or hot-air engine, the latter actuated by a gas flame. It is, therefore, self-contained. A large number of styles and patterns of beautiful lanterns and indoor fittings, with special burners, have been brought out to go with the "Sugg" systems of high and low pressure lighting. These lamps are often used with other systems of producing the light.

Several systems, mostly of Continental origin, as the "Millennium," "Pharos," and others that arise from time to time, with one English system, the "Sale-Onslow," work at pressures rising to 50 inches. The efficiency of the lighting is as high as 40 candles per cubic foot, with double mantles. This makes splendid lighting for workshops, literally turning night into day as regards facility for working and handling goods, and furnishing an excellent

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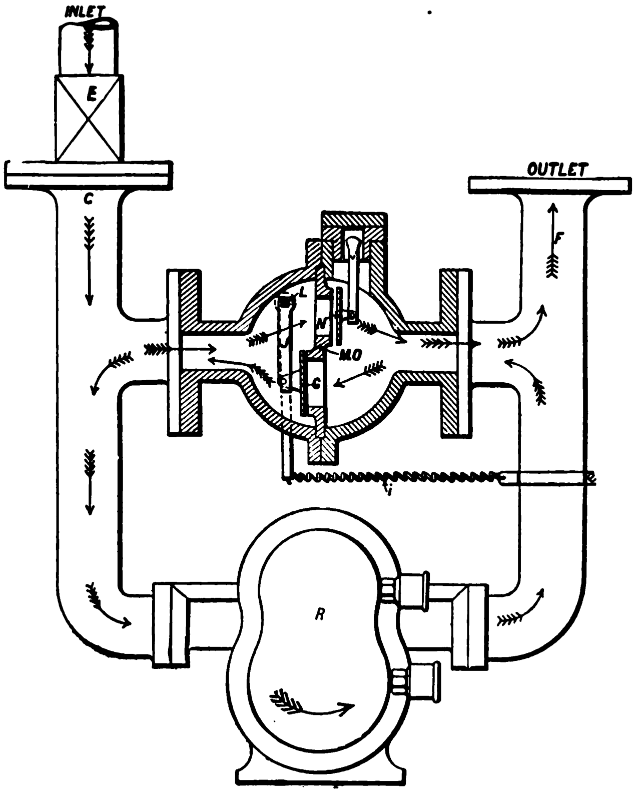

FIG. 34.—The Sale-Onslow Compressing Machine ; capable of working up to a gas delivery pressure of 100 inches of water (3·7lbs. per square inch). R, blower, driven by gas, steam, or electric power. Parts of relief valve, shown in section: N, ordinary escape valve for compressed gas; G, safety valve, permitting back-flow, weighted by lever L; E, gas inlet; F, gas outlet.

light for railway stations and goods-yards (Fig. 34). Gas distributed at any pressure can be reduced for the supply of the signal lights if required. Examples of successful high

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pressure gas lighting are to be found in all parts of the world, in London specially in front of Buckingham Palace, Parliament Square, the Mansion House, the streets of the City of London, Kingsway, the River Thames bridges, the new Victoria Station, Broad Street Station, etc.

One system, the "Selas," mechanically mixes air in equal proportion with the gas, thus obtaining an extremely good effect both for small and large lights. The system is well recommended for mills and factories. The mixture is non-luminous without a mantle, so that a light cannot be had with a flame burner. Other systems have been put upon the market in which the air supply, not the gas, is under pressure. This brings no additional strain upon the gas piping, and quite closed lanterns can be used. It should therefore be advantageous in very dusty atmospheres, as those of some textile mills, and cement works.

It has been demonstrated experimentally, that in the event of cheap supplies of oxygen gas being made available by the liquid air process for separating the atmospheric oxygen from the nitrogen, a double system of oxygen and town gas distribution would enable lights to be run at an efficiency which might easily surpass 100 candles per cubic foot of town gas ($E = 100$ candle power); but this possibility is only hinted at here as an indication that the ultimate limits of the luminous capabilities of the incandescent gas mantle are by no means reached by present practice.

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CHAPTER V.

PRACTICAL GAS LIGHTING.

Definition of the science of artificial lighting—Terminology—The law of radiant energy—A working standard of illuminating effect—Lighting and visibility—Physiological considerations—A domestic example—Calculations of lighting effect—Simple rules—Lamp shades and reflectors—The lighting of shop windows—The lighting of public halls and churches—Factory and workshop lighting—The lighting of railway goods-yards, wharves, quays, etc.—When high-pressure lighting is expedient—Public street lighting—Its principles and methods.

The science of artificial lighting relates to the proper selection and disposition for the purpose intended of suitable sources of light. Whatever the nature of the illuminant, its application to outdoor or indoor lighting is subject to the same general principles, which in turn refer to physical, physiological, and economic considerations. This particular department of applied science has hitherto been sadly neglected, both by those whose business it is to provide the means, and those who require good and satisfactory lighting. It is one of the principal objects of this book to state in such plain language the fundamental considerations which must be satisfied by all successful schemes of artificial lighting, that purveyors of the means and those whose wants are in question, being in mutual possession of the data, may meet on the common ground of an adequate and just appreciation of the conditions of success.

In order to avoid tautology and confusion, in what follows the source of light will be called the "lamp," the

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word "light" being reserved for the intrinsic brilliancy of the source, in terms of candle power. The effect produced by the light at a distance will be called "lighting," and will be measured in "candle-feet," a compound unit derived by dividing the number of candles indicating the luminous intensity of the lamp by the square of its distance in feet from the surface illuminated. This rule of measurement is based upon the law of luminous radiation, which is deduced from the geo-metrical properties of the circle and sphere. Suppose the lamp to be a point in space, and its light, of a certain intensity, to be radiated equally in every direction. Take one ray. At the distance of 1 foot, this luminous intensity will be spread over an area of 1 square foot, as in the diagram (Fig. 35). We assume that every point in this area is receiving light of unit intensity. The same radiation proceeds outwards in radial lines, until at *twice* the distance, 2 feet, it has to spread over *four times* the surface, because the surfaces of spheres are to each other as the squares of their radii. Thus, every point of the sphere that would be described in space by taking *twice* the radius unity (1 × 2), only receives *one-fourth* of the intensity of the radiation existing at the unit distance. Hence the rule that the luminous intensity of lighting, measured in a straight line from the source of the light,

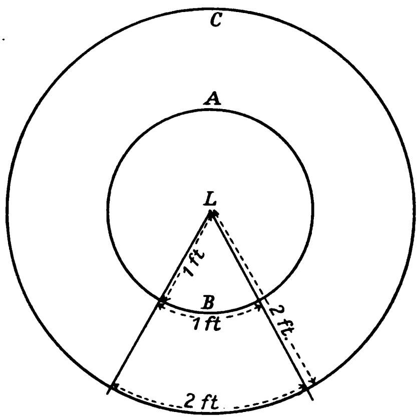

FIG. 35.

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diminishes as the *square* of the distance. This is true, for if we can just see to read by the light of a candle 1 foot away (1 candle-foot), at double the distance a light of four candles will be required to enable us to see as well, and so on.

In practice and in fact, this standard of lighting, namely, the amount of illuminating effect produced by the light of one candle at a distance of 1 foot, or 1 candle-foot, is usually adopted as tolerable lighting for all ordinary purposes of reading, writing, and social intercourse indoors. It is a simple, easily-remembered quantity. It must be connected, however, with some definite receiver of the illuminating effect, say a book, or a table or desk at the ordinary height from the floor of the room (2 feet 6 inches), the distance of whose surface from the lamp can be measured, and referred thence to the quantity of light entering the eye.

We have now carried the process of reasoning out the simplest problem of lighting into the region of practical experience, and shall understand better how to solve all such problems by following the developments of a particular case.

What is really meant by the statement that a candle-foot is tolerable lighting for the purpose of reading? Clearly, that such lighting of a sheet of white paper enables the human eye to read reasonably distinct black printed (as type of this size) or written characters upon it. The judge of what is required here is the eye, whose needs must therefore be the first consideration in the matter. In most previous writings on the subject of lights and lighting, the requirements of the eye are little, if at all, regarded: the study of the effects starts with the lamp itself; and it is left to be assumed that the more light there is provided, the better the lighting. This is almost as sensible a method of

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treating the matter as the putting of a hungry man into a butcher's shop and expecting him to be satisfied. Here the opposite plan will be followed, and an attempt at least made to place the solution of artificial lighting problems upon a sound physiological basis.

Assuming the act of reading from white paper to be the test of tolerable lighting for a living room, and the standard of efficient lighting proposed that afforded by a candle at a foot distance: The first important condition to notice is that the candle does not shine directly into the eye which is reading by its light; but the eye receives the light reflected from the white paper. Incidentally, let it be laid down that this elementary rule of the relations of the lamp, the object lighted, and the eye is invariably correct. The eye should never seek the source of light, but always be rendered active for perception by irregularly reflected—*i.e.*, diffused lighting.

Note.—The term "irregular" reflection is employed in this connection in its scientific sense, meaning all lighting by virtue of which the eye sees objects; the term "regular" is applied in the Science of Light to reflection from mirrors, or mirror-like surfaces, such as still water, which gives in the eye an *image* of the reflected object. The former constitutes *lighting*, the latter does not.

Assuming further, for the sake of simplicity, that the white paper is a perfect diffusive reflecting surface, so that the whole of the light received from the candle is directed into the eye without loss, it is to be concluded that the human eye can see tolerably well with this intensity of light passing the adjustable iris and striking the sensitive retina. If we examined it, we should find the iris opened to a certain extent. Supposing, now, the brightness of the lighting to be doubled, so as to send into the eye the equivalent light of two candles. One effect would be that printed

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characters on the page, previously almost illegible, as in this sized type, could be read. Another effect would be a slight, yet noticeable, contraction of the opening of the iris of the reader's eye. Increase the lighting further to the equivalent of 3 candle-feet, and the normal requirements of vision for reading print will be sensibly exceeded. The iris will be much contracted. At 4 candle-feet the eye refuses to tolerate the reflection from white paper, and the eyelid will drop over it. Much brighter lighting, however, will be appreciated if the object in the field of vision is watchmaker's work, engraving, or black sewing, for a reason to be presently explained.

It appears from this statement of the matter, that the eye has no use for reflected lighting offered to it at a higher intensity than about 3 candle-feet. Similarly, the eye ought never to be exposed to the direct rays of any light of much higher intensity, say, than 5 candle power per square inch of the visible area of the illuminant. It is difficult to prevent the eye from catching sight of a source of artificial light in its vicinity; therefore, where such illuminants are of higher intrinsic brilliancy than candles or luminous gas flames, they should always be carefully shaded down to the permissible limit of intensity here [illegible]

[illegible] intensity of what can be properly [illegible] it is impossible to put a figure. It [illegible] to be served. For public halls [illegible] intended to be fairly equally lighted in [illegible] candle 0·5 candle-foot on the floor is [illegible] about the minimum for [illegible]. How this is ascertained will be explained further on. Lower rates of lighting and unequal lighting [illegible] are to some extent matters of taste. [illegible] ordinary purposes of

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working or entertainment a fairly uniform distribution of lighting is to be recommended as the groundwork of the scheme, with the addition where required, as at the desk, or the pianoforte, of any brighter local illumination which may be called for. Even for a private study, concentration of the reading light upon the table, with the rest of the apartment in gloom, is not conducive to a comfortable use of the eyes. This is because the iris accommodates itself to the brightest light in the field of vision, and is not prepared for any attempt to look beyond it. When subjected to violent alternations of light and darkness, the retinal impressions become irritating and unsatisfactory.

Outdoors, the intensity of natural light that renders vision possible varies through an enormous range. It was observed by Helmholtz, that within very wide limits of brightness our perception of objects is unaffected by the actual amount of light shed upon them so long as the relative balance of light and shade remains constant. And our power of seeing familiar and accustomed objects at night, such as the lie of the land or lights at sea, requires so little actual stimulation of the eyes by light, that the perception of such objects appears marvellous to anyone who does not sufficiently consider in this connection the saying of Goethe that "we see what we know." We shall return to this part of the topic when discussing public street lighting.

Returning to the consideration of what is serviceable lighting for indoor use, and to the physiological standard of adequate illumination of the eye for working purposes as lying between one candle and three candles, we can proceed to frame a simple scheme of domestic lighting which will satisfy this prescription. Let us therefore assume the common case of a small dining-room, 13 feet by 15 feet,

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with a whitened ceiling and dark walls. As the most brilliant light is required to be shed upon the centre table at which the ordinary uses of the apartment are fulfilled, the lamp must be hung over it in the middle of the room. Under these conditions the problem may be stated as consisting in providing a normal illumination of not less than 1 candle-foot on the eyes of a person reading at the table;

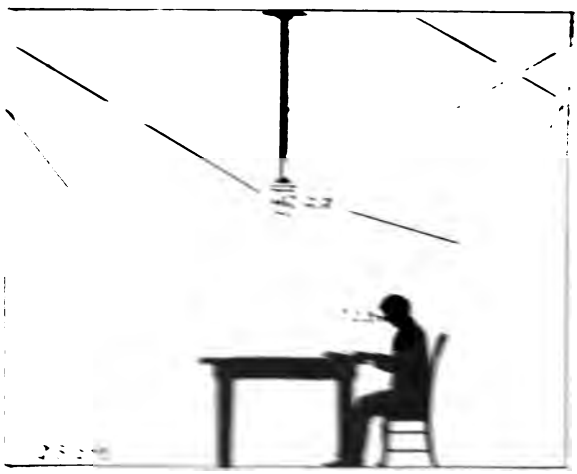

Fig. 36. Simple lighting of a dining room.

such illumination to be capable of being increased to 2—3 candles if required (Fig. 36).

Certain measurements in this case are fixed, and must be reckoned with. The lamp, being a fixture, hangs at a height of [illegible] feet [illegible] inches above the floor, so as to be well out of the way when the table is removed. The surface of the table is 2 feet [illegible] inches above the floor. The distance from the lamp to the table exactly underneath it is therefore 4 feet. The distance from the table to the eye of a person sitting to read or write is about 1 foot [illegible] inches. Consequently, the total

length of the ray of light from lamp to eye, is 5 feet 6 inches. In its path is the reflecting surface of the printed white paper, which does not reflect more than 70 per cent. of the total lighting it receives. The average reflecting power of various substances of common occurrence in or forming the surface of the walls of a room is given in the following table (Bell):—

Material.	Percentage of Diffuse Reflection.
Clean white blotting paper	82
" " cartridge "	80
Common foolscap (or a printed page)	70
Chrome yellow wall-paper	62
Orange " "	50
Clean planed deal	45
Light-painted or distempered wall	40
Emerald green paper	18
Dark brown paper	13
Cobalt blue "	12
Deep chocolate "	4
Black cloth	1·2
Black velvet	0·4

It will be seen from this list that apart from the shiny and pure white surface of paper, to which may be likened a white table cloth, and of a white ceiling, most surfaces do not reflect much light. Even with the ordinary book or newspaper, which ranks with foolscap, there is a loss of 30 per cent. of the incident light, which in the case in point must be allowed for. The ceiling being white, we may expect it to reflect a good proportion of the light shining upwards from the lamp; but there will be no appreciable reflection from the wall-paper.

Now, the conditions call for a total light sufficient to produce a lighting effect of not less than 1 candle-foot at

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[illegible] distance [illegible] will [illegible] 30 per cent. on the [illegible] distance squared [illegible] ratio of the [illegible] distant effect. In [illegible] number of [illegible] proportion lost. [illegible] candles as the [illegible] required lamp. This [illegible] incandescent [illegible] or by an [illegible] gas per hour. [illegible] The [illegible] pleasing [illegible] an agreeable [illegible] special [illegible]

[illegible]

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general rule, which has already been stated in the observation that an average distribution of illumination working out to 0·5 candle-foot over the floor area, is the accepted minimum for a cheerful effect. Applying this rule to the case of the dining-room we have been considering on another basis, we shall find that the greatest distance from the central lamp to a wall at the floor level is a little less than 10 feet. The intensity of the shaded lamp is assumed to be 40 candles. Therefore, the lighting at the skirting is $\frac{40}{10 \times 10} = 0{\cdot}4$ candle-foot. Add 25 per cent. for the diffused reflection from the white ceiling, and we again get the total effect equalling 0·5 candle-foot, as required.

Again, it is an accepted rule of technicians for good average lighting, that the quantity of light provided should work out to 1 effective candle power to every 3 square feet of floor area. Our example, a room measuring 15 feet × 13 feet, has a floor area of 195 square feet. Dividing this by 3, we get 65 as the figure for the effective candle power, which is near enough to the unshaded intensity of our chosen lamp, with the added reflection.

The room being about 10 feet 6 inches high, will have a capacity of about 2,000 cubic feet, so that the gas consumption for satisfactory lighting will be not more than 2 cubic feet per hour, per 1,000 cubic feet, of this order of interior space.

Carrying these data in mind, it is easy to arrange any larger scheme of interior lighting satisfactorily. If the nearest attainable uniformity of diffused illumination is called for, the mathematics of the case show that the lamps must be spaced 1½ times their height apart. Lamps are often fixed closer together than this; but the reason then is decoration, not efficient lighting. Spacing at twice the height is practically as good as 1½ times when the diffused

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reflection is fairly bright. Semi-open spaces, suc railway station platforms, offer a fair approximati uniform lighting at 5-times spacing, provided the refle of the lantern top are suitably designed. This is, how the widest lamp-spacing that should be countenance "still-life" lighting. For moving traffic, which constantly passing at intervals of a few seconds from brighter-lighted area to another, the spacing may considerably greater.

For domestic and shop lighting, lamps in a row sh not be wider apart than twice their height. What height should be is governed by the situation; and in t governs the intrinsic brilliancy of the lamp. The con tions are best given in the form of a table, as follo for equal floor lighting:—

ARRANGEMENT OF INTERIOR LIGHTING.

Height of Lamp.	Spacing.	Illuminating Power (naked mantle).
6 ft. 6 in. (domestic)	10 ft. to 13 ft.	50— 60 candles.
9 ft.—10 ft. (retail shop or workshop)	15 ft. to 20 ft.	100—150 ,,
13 ft.—18 ft. (warehouse)	22 ft. to 35 ft.	200—400 ,,

Lamp Shades.—All actual lighting is, of course, due t reflection of light from objects into the eye, which the perceives and locates them, partly by what can be distinguished, partly by what is known beforehand about them. The eye never wants to see the source of light, except when this is itself the object of vision, as in the case of a lighthouse, signal, or warning light. In all practical lighting, therefore, the lamp should either be kept out of sight, or if this cannot be managed, its brilliancy must be reduced for the eye by an intervening shade which only permits direct vision of a lamp of a harmless degree of intensity. Consequently, it is usual to employ milky, or

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so-called "opal" glass lamp shades for the purpose, which seem to obstruct a large proportion of the light, inasmuch as they actually do stop from 30 to 40 per cent. of the straight-line radiant intensity. The true loss of useful visual effect by this reduction of intensity is not, however, nearly so considerable. It has been stated that the eye can see equally well in a general way with widely different degrees of illumination, and also that the extent of the opening of the iris is regulated by the brightest light in the field of vision. Clearly, therefore, a bright lamp which tends to close the eye not only against itself, but also against everything else, is no aid to vision, which will be far more effective when there is no such blinding influence in its field.

It is not necessary, in the case of a gas lamp, to use so opaque a glass shade that the mantle cannot be seen at all. All that is needed, even for inverted or other lamps close at hand, is just enough obscuration of the glass to moderate its brilliancy so that nowhere shall this exceed the intensity of a luminous gas flame, namely, 5 candles per square inch of illuminant, viewed as a plane figure. This is a degree of brilliancy which the normal retina endures without suffering, and without experiencing that "glare" or dazzling which leaves distress behind it, as shown by the persistence of a coloured "after-image." It is easy to conform to this rule by providing that gas burners, when liable to be viewed at close quarters, shall be shaded by opal or other partially obscured glass having a visible surface of 10 square inches for every 50 candle power *transmitted*. It is seldom necessary, moreover, to enclose the whole of the radiant within an opaque glass box. Rays proceeding in directions not permitting direct vision of the mantle until distance has itself reduced the intensity of the light to a harmless degree, may be allowed to pass undimmed.

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Several patterns of reflector and shade, in combination, offer this advantage. Inverted lamp glasses may be open at the bottom, because the eye cannot look vertically upwards and so catch sight of the mantle at its brightest, while having their deepest obscuration at the lower edge, which intercepts a glance raised to an angle between 60° and 45°. Cut-glass shades break up the direct rays, and so disperse the lamplight without actually obscuring it. In the "holophane" globes the facets of glass are so disposed as to improve the distribution. The liability of all cut and roughened glass to collect dust, and so appear dingy by day, is a drawback to its use.

Reflectors, forming part of a lamp or lantern, are intended to improve the effective distribution of the light by turning those rays which, by the form of the radiant, would be shed in directions where their light is not wanted, in other directions where it will be most useful. In order to explain the principles of this "regular," or mirror-like reflection, it will be necessary to devote a few words to the subject of the total radiation of light from a lamp. In what has been stated hitherto respecting the luminous intensity, or illuminating power, of a lamp, what was referred to, and calculated with, is the equivalent number of candles representing the luminosity of the light shining in the horizontal line. It is the measure of intensity of the light shed in one direction, and that the horizontal one. If we look straight at the lamp, on a level with it, this is the valuation, in terms of candle power, of the light we see in the direct line joining our eye and the lamp.

It is obvious, however, that a lamp gives its light in all directions, radiating from the centre of a sphere. Hence the correct mathematical expression for *total* radiation is the ratio of the surface of a sphere to its radius. The surface of a sphere of radius = 1, is 12·57 nearly. There-

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fore, the figure representing the total radiation of a lamp, assumed to be giving the same amount of light in every direction, is arrived at by multiplying the intensity by 12·57. It is by virtue of this spherical radiation that "search-light" beams are made up by a cleverly-formed system of reflectors and refracting lenses, which sends out as much of the total radiation as can be collected in a nearly parallel bundle of rays, carrying their luminous intensity to a great distance. Ordinary lamp reflectors are simple embodiments of the same principle. Where lamp-light is wanted downwards, and not upwards, a top reflector is put on, which increases the downward illumination at the expense of the upward rays. Something of the kind is generally adopted for upright incandescent gas burners, which naturally have a poor downward radiation, and throw shadows from the burner-fitting.

Desk lamps of this kind usually have a highly-reflecting, opaque top reflector, which will give a downward light of 100 candles or more for 3 cubic feet of gas an hour; and they should also have saucer-shaped opal eye shades below, to prevent direct vision of the mantle and the intensely brilliant underside of the reflector. Similar top reflectors, of opal glass, let a little light through, and consequently have a more cheerful effect. It is a safe rule to lay down for the lighting of interiors, that bright naked lamps of any kind should *never* be used. Many forms of gas lamps are made with shades and reflectors as integral parts of their structure, and in choosing these it is only necessary to bear in mind the purpose for which the lamp is wanted. The various uses of reflectors are indicated in the diagrams (Fig. 37). The smallest translucent top or side reflector will suffice to dispel a shadow, or throw a better light in a particular direction, without detracting noticeably from the general illumination. The angle of

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FIG. 38.—A Draper's Shop, brilliantly lighted by gas. (Photographed by its own light.)

reflection being equal to the angle of incidence, steep-topped reflectors will concentrate the light downwards, and wide, or reversed ones, will scatter it abroad.

Shop and Window Lighting.—The cardinal rule to be observed in lighting shop windows is the same that applies to domestic and office lighting, namely, that the sources of the light should be out of the line of sight of persons enjoying the use of it. Although this rule is generally observed in interiors, if only for the very good reason that it is necessary for the lamps to be fixed out of harm's way overhead, yet in the lighting of shop windows it is frequently ignored, and the lamps mixed up in a most distressing way with the goods they are supposed to set off. Often the windows are so arranged that the eye of the passer-by insensibly seeks the lamp itself, instead of the stock-in-trade. Sometimes outside hanging lamps of such glaring brilliancy are placed in front of the window, that wayfarers are driven away from the spot. This is a mistake. The best lighting should be inside (Fig. 38).

For the generality of shops the window lighting can be most economically and effectively contrived by fixing a row of incandescent burners inside the window, well above the line of sight of persons in the street, with reflectors to throw the light downwards. The lamps will then never be seen, whilst the brilliancy and attractiveness of the show is only limited by the amount of light provided. The heat and products of combustion of the gas will not touch the window dressing, and can usually be ventilated out through a perforated frieze over the glass front.

Outside hanging lamps are chiefly desirable when the shop window is dressed right against the glass, which is a tasteless mode. Where used, they should be of a high order of brilliancy to do any good. It is a question whether the same quantity of gas burnt in private street lamps

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Fig. 39.—Church Lighting.

placed along the kerb is not more effective in attracting the public. Really important emporiums should, in addition, hang some bright lamps on the frontage, at the first-floor

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level, or even higher. This has a very smart effect, especially where the approach is spacious.

THE LIGHTING OF PUBLIC HALLS.—This calls for such an arrangement of the lamps that they do not come between the audience and the platform. For this reason lamps or chandeliers of considerable power, proportionate to the size of the interior, should be fixed fairly high up, in rows on each side of the main axis of the hall, and nearer the walls than the middle. Where the size or shape of the interior calls for centre lighting, this should be arranged for close up to the ceiling. Baths and gymnasia are also best lighted in this way. If the ceiling over the lights is kept whitened, the lighting effect is much enhanced. The standard of illumination of public buildings of this kind should be 0·5 candle-foot on the floor. In some highly-decorated halls the lighting is done from the outer side of a glazed ceiling cove or fanlight of tinted or obscured glass. This is very soft and decorative, but expensive.

THE LIGHTING OF CHURCHES.—In buildings of this class, even more than with assembly rooms, the lighting must be kept subservient to the principal uses of the structure. While offering a distinctly decorative feature, if sought for, and harmonising with the architecture of the building, church lighting should never obtrude itself as an ornament in itself. Unfortunately it is often conspicuously otherwise. The necessity for a shadowless general illumination, for the purpose of enabling the congregation to read the usually small print of the service books, has in the past imposed upon ecclesiastical gas fittings a style of multiplied, inclined, or horizontal flat-flame burners which are the least efficient of any for the quantity of gas consumed. These lights fulfil the requirement of unobtrusiveness; but the superfluous heat of their excessive gas consumption has given gas lighting for churches an undeserved reputation

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FIG. 40.—Lighting of a Printing Machine Room.

for causing stuffiness. Another good way of lighting a church to the satisfaction of the congregation, at a moderatecost, is by suitably placed inverted gas lamps, borne

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on standards firmly fixed to the floor. Standards already in use can usually be adapted to this mode of lighting, which readily lends itself to any style of architectural fitting. A

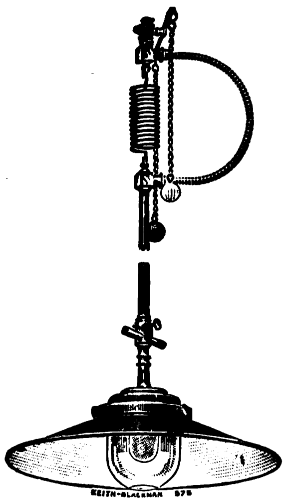

FIG. 41.

FIG. 42.

diffused illumination of 0·5 candle power on the floor, will prove adequate. No help from reflection is to be expected in most examples. Means of lowering the light must usually be provided. It should not be overlooked that

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lighting a church by gas properly applied, incidentally prevents the discomfort of "downward draughts," because its gentle, diffused heat tends to keep the roof space warm.

THE LIGHTING OF FACTORIES AND WORKSHOPS.—The arrangement of the lights in industrial buildings should be governed by the character of the work carried on and the needs of the individual workers (Fig. 40). The brightest lighting is required by sewing machinists, and must be thrown on the proper side of the needle. High-pressure gas in small inverted burners, with top conical opal shade-reflectors, hanging within 30 inches of the work (Fig. 41), one to every machine (or pair, if opposite) gives complete satisfaction in large shops. The small consumption of the burners (1 cubic foot per hour) does not appreciably raise the temperature of the room, whilst the upward current of air induced by the burning gas helps to ventilate the space round the worker. The general lighting of the room can be provided for by a few larger and higher lamps, with upright mantles (Figs. 42 and 43).

FIG. 43.

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The same style of lighting can be applied, with the necessary modification for the particular circumstances, to all bench work. Where the workers move about, the lights must be raised out of their way. In workshops with glazed roofs, which do not reflect light at all, a good effect of lighting and great economy can be secured by the use of high-power lamps, placed underneath large whitewashed board reflectors.

Railway Goods-Yards, Wharves, Quays, etc.—Strong lamp-posts, or wall-lanterns with good top reflectors, are best for such applications, with double burners. Good distribution, the avoidance of sharp shadows, and absence of any blinding glare, are the best conditions for getting the utmost amount of work done by artificial light. When properly disposed, such lighting pays for itself many times over in increased output.

Unless otherwise specified, it is to be understood that inverted gas lamps are to be employed chiefly for small powers, in single lights, and indoors. For high-power lights, and out-door lighting, the upright type of mantle burner is usually to be preferred. Particulars of the fittings employed for this purpose are to be found in technical publications.

A question often asked by large users of light for drapery establishments, warehouses where heavy and bulky goods are handled, etc., is as to when it pays to put down pressure plant, instead of using the gas at the ordinary town pressure. The answer depends upon what the latter pressure is, normally; and also upon the scale of lighting required. As already remarked, since the general introduction of the incandescent system of lighting, which is essentially a high-pressure system, town gas has everywhere been distributed at far higher pressures than formerly. There are few districts regarded as adequately served with gas at

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the present day, where a pressure of from 25 to 30 tenths cannot be had during lighting hours, at the point of consumption. This fact materially affects the case for assisted-pressure arrangements, the necessity of which is more apparent when the town pressure is not more than 10-tenths, or so, which was at one time general. It comes to this: Where the ordinary main pressure is kept at the higher figure mentioned above, both inverted and upright mantle intensities are so good, that exceptional conditions must be in question before the idea of putting down special increased pressure plant need be entertained. All the brilliancy of illumination usually necessary or desirable even for elevated or out-door lamps, can be had most conveniently and effectively by doubling or trebling the number of burners in proper reflector lanterns.

The same remark applies with equal force to public street lighting. Up to widths of thoroughfare, from front to front, not exceeding 50 feet, the best possible illumination is obtainable by reducing the spacing of the lamps along the kerb lines, and doubling the burners in the lanterns, half the burners being extinguished after the busiest hours, if economy is to be considered.

There is a scale of lighting, unquestionably, at which the economy of high-pressure light, to say nothing of its brightness, outweighs the small additional cost of the necessary plant; and in the case of business premises of the kind above-mentioned, this consideration begins to impress itself on the lighting bill when it refers to upwards of 4,000 candle power of illumination. In the case of a clothing factory, the desirability of a very brilliant scheme of distributed lighting may turn the scale earlier. For large mills, or engineering works, there can be no question of the superiority of the highest-pressure systems of incandescent gas lighting over all others, even if they cost more. There

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FIG. 44.—High Pressure Lighting in front of the Royal Exchange, London.

are other cases, as for example the lighting of the largest railway stations, and the widest streets and centres of traffic of capital cities, which no other means of artificial lighting is competent to illuminate so well, regardless of cost, which comes out very favourably to these systems, as will

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be shown later (p. 161). In short, wherever a flood of light is wanted, and circumstances preclude any attempt to provide it by simple multiplication of the comparatively small units obtainable from ordinary main pressure supplies, the choice of a high pressure system in indicated. It is advisable to consult the gas company as to the plant most suitable for the particular purpose, including the proper patterns of the lamps and their disposition to the best advantage. The after care of the installation can usually also be arranged for in the same quarter (Fig. 44).

Seven Simple Rules for Good Gas Lighting.

1. Do not put an incandescent gas light in the line of sight; but always above it if possible.

2. Never use an incandescent light without a reflector over it; or to throw the light in the direction where it is most required.

3. If an incandescent light is likely to meet the eye within a distance of ten feet, it must have an opal shade, independent of the reflector.

4. Allow for interior lighting by pendant lamps, one "C," No. 2 Kern, or a full-sized inverted lamp to every 150 square feet of floor area. For "Bijou" inverted lamps, use thrice the number if pendant; or four times if on brackets. This rule applies to lights at the usual domestic height of 6 ft. 6 ins. above the floor. At the usual shop height of about 8 ft. 6 ins., double the number of lights.

5. The most equal distribution of light is given by lamps spaced at one-and-a-half times their height apart.

6. Use pilot-light burners for shops, workrooms, etc.

7. Outside shop window lamps should be as low and as far off from the glass as possible.

Public Street Lighting.—Although some of the more salient requirements of this application f gas light have

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been touched upon incidentally in the foregoing pages, it is desirable that the subject should be discussed by itself; as it really is a distinct study of the lighting engineer, into which an immense variety of considerations enter, including the views of the "man in the street." No department of the art and business of lighting has been more mishandled than this, by professedly scientific persons on the one side, and by highway authorities, professedly economical, on the other. Only quite recently, after many experiments, has anything deserving the name of sensible street lighting practice been evolved; and even now this is often outraged by local authorities allowing themselves to be swayed by considerations other than the requirements of traffic.

In order to understand these requirements, and decide upon the best means of satisfying them, it is necessary to distinguish between the technical meaning of the term "lighting" as applied to the public street lamp service, and its natural meaning, of illumination, which we have hitherto been considering. With few and rare exceptions, as of streets which rank as promenades, and the principal centres of traffic in cities, public street lighting is not "lighting" at all. That is to say, its purpose is not the equal illumination of objects, by actual lighting capable of being measured instrumentally in terms of candle-feet. It is more properly to be classified as beacon lighting, inasmuch as its purpose is more akin to the "lighting" of a coast line, than to the ordinary purposes of interior illumination. It is designed to facilitate moving traffic, and also to subserve the police protection of the public, not to enable people standing about in the streets to read newspapers. Forgetfulness of this simple fact has in times past misled highway authorities into sanctioning absurdities, such as the "tower" lighting, which was an American craze of the "eighties" of the past century; and still permits

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their indulgence in the fallacy that electric arc lamps are suitable for lighting suburban roads, if only they are placed far enough apart.

Fig. 45.—Street Lantern for Incandescent Light.

Anything approaching equal diffusion of light over a public road is impracticable. In the simplest case, of suburban roads, every requirement is satisfied by the use of Welsbach "C," or Kern No. 4 incandescent gas burners, in stout, well kept-up reflecting-top lanterns (Fig. 45), spaced at intervals, the length of which is governed by the character of the thoroughfare, and the volume of traffic. Where there are no houses and few cross roads, the lamp-posts may be spaced 80 yards apart, as their main purpose is to show the trend of the road, and the nature of its surface. The more populous the district, the thicker should be the lamp-posts, without altering their lamp-fittings. With such lamps, spaced 50 yards

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apart, it is possible to see the time by a watch anywhere in the road, and also to read an address card or envelope. Such road lighting gives a cheerful effect to a town, and as there is no glare, the drivers of vehicles are not incommoded by the lamps. For the latter reason, the public lighting of a common high road by units of moderate intensity is much to be preferred to the employment for this purpose of powerful units of any kind. Physiological considerations, in fact, as already discussed, enjoin the thickest placing of the strongest lights, which, of course, considerations of economy usually forbid for out-doors. The expressing of the value of road lighting in candle power, is therefore worse than inappropriate to the requirements of the traffic; it is actively misleading, and, as a rule, is seldom mentioned in this connection unless to excuse an extravagant outlay upon a wrong system. Ordinary gas lamps with top reflectors and plain glass lanterns represent about 1,000 candle power of spherical light radiation (p. 134). Twenty-two to the mile will therefore represent 22,000 candle power, exhibited in as many alternations of light and darkness. An ordinary electric arc lamp in a thick opal globe may have an effective spherical light radiation of 4,000 candle power, and be spaced 12 to the mile; which would give a total light effect of 48,000 candle power, divided up into twelve patches of light in the prevailing darkness. Although the nominal candle power of the more powerful light figures out to more than double that of the smaller units, most of it is superfluous where it occurs; and the light of the smaller lamps is so much more serviceable as it is never in excess, and is far less patchy. From every point of view of the wayfaring man, whether moving on foot or driving any form of vehicle, the more frequent and less dazzling light is the better. The police testimony is to the same effect. Too strong a light in front of a dwelling house, moreover, is a nuisance, especially where such lamps

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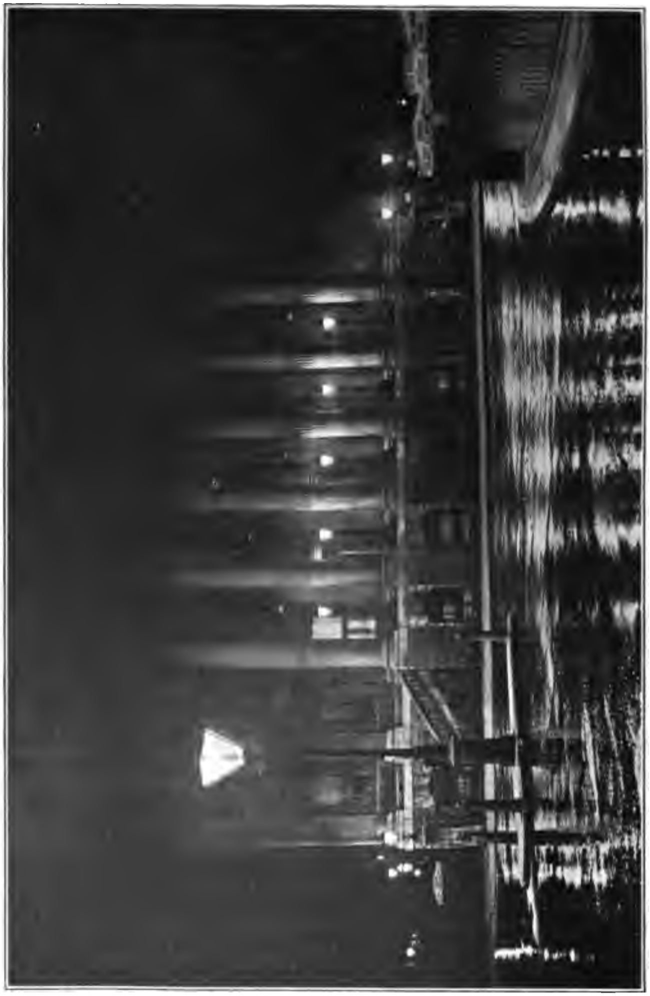

FIG. 46.—High Pressure Lighting in front of the Mansion House, London.

are hung at the height of the bedroom windows. Therefore, on all these different and important grounds, the choice is debarred of powerful lamps for public street lighting, under

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conditions other than those prevailing in the case of boulevards, where the lighting is on the lavish scale of an illumination; or in the more important main thoroughfares and "places," measuring 80 feet or 100 feet and upwards across. On electric tram-lines the posts are convenient for fixing the lamps upon.

Sometimes, for the sake usually of economy, public street lamps are placed in a line along the middle of a fairly wide street. This is bad, on all counts. It is wrong for the wheeled traffic, one half of every vehicle being always in shadow. People crossing the road, must go the second half of the passage in their own light. The lettering on omnibuses cannot be read from the footpath. The necessarily frequent "refuges" surrounding the lamp-posts are a grievous obstruction to traffic, and render the road unfit for processions. In a word, lights along the centre line of a street are in the worst possible place for every use of the roadway.

The illustration shows a good recent example of high-pressure street lighting in London (Fig. 46).

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CHAPTER VI.

THE COST OF GAS LIGHTING.

Description of gas meters—Reading the index—The prepayment meter—What a pennyworth of gas will do—The cost of gas lighting—Examples from experience of various systems.

THE cost of gas lighting is very easily ascertained, as it depends chiefly upon the quantity of gas consumed, registered by the consumer's meter, and charged, in the United Kingdom, at per 1,000 cubic feet. Public street lamps are usually served and maintained by contract at so much each per annum; and some other lights of a similar class are also commonly supplied at a contract price. The great bulk of the supply of town gas, however, is metered, and a brief description of the method of ascertaining the quantity consumed, as registered by the meter, may not be out of place, as few people understand its working or appreciate its many excellent qualities.

Consumers' gas meters (as described in Chap. II.) are of two kinds, "wet" and "dry." In the former, the current of gas flowing towards the points of consumption turns a water-wheel formed like a drum, the capacity of which and the rate of its revolution measure the gas passing within a stated period of time. The movement of the drum is communicated to a train of wheels, whose revolutions are indicated by pointers on a series of dials figured in decimal multiples of a cubic foot (Fig. 47). The correctness of all gas meters is guaranteed by Government inspection, every instrument having to be tested and stamped before being

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issued for use, which is only done when its margin of error is under 3 per cent. in favour of the consumer, or 2 per cent. in favour of the seller of gas. In reading the meter index, begin with the dial on the right, which indicates the smallest measure, and take the *lower* of the two figures between which the pointer happens to stand. Then proceed to take the lower of the figures similarly indicated on the next dial, always remembering to note that the figures go the opposite way in each successive dial. Having thus booked the lower

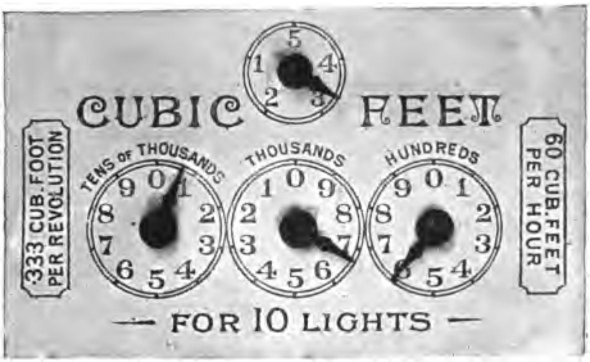

FIG. 47.

indicated figures on every dial, you will have what is called the register of the meter. If from this is deducted the registration at any earlier period in question, the difference is the gas consumption for the interval.

Sometimes it is difficult to make out from a particular dial whether the pointer has actually passed a figure by which it appears to stand. This information is furnished by the next lower dial, that is, the one to the right. This will show, by the pointer standing short of or past the zero, whether the revolution has been completed (except in the case of the extreme right-hand dial, which does not

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matter, because if wrongly read the error will be corrected next time). The index in the figure reads "6,600 cubic feet."

"Dry" meters are preferred by consumers to the wet kind, because there is no water to cause trouble by freezing at inconvenient times. All meters, however, deserve more

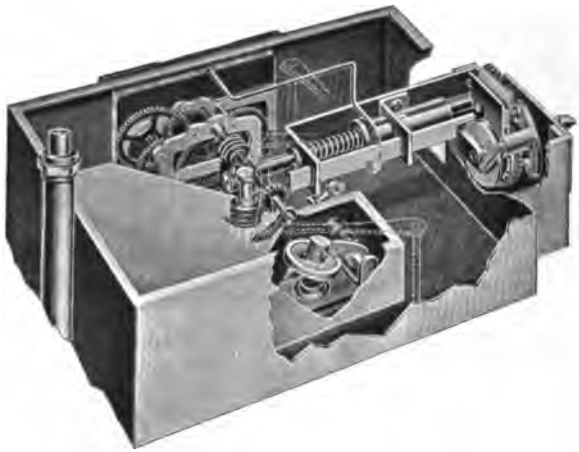

FIG. 48.—Slot Prepayment Meter Attachment. Coin-controlling mechanism attached to dry gas meter (Cowan's patent). On the extreme right is the "coin-wheel," carrying the coin round a determined portion of its revolution, by which the gas valve is set open by a corresponding degree. As the gas thus paid for passes through the meter, the valve automatically closes.

considerate treatment and housing than they sometimes receive. The place where they are kept should at least be dry, and of a fairly equable temperature. The measuring apparatus of dry meters is a double bellows, made of tin and soft-dressed leather, one half filling with gas as the other empties itself. The indexing is the same in all meters.

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Of late years an enormous vogue has set in for mechanical prepayment, or, as they are commonly called, "slot" meters (Fig. 48). Hundreds of thousands of these "boons and blessings" to the poorer class of town householders are in use, and the demand seems to be still increasing. The slot meter has wrought a veritable revolution in the domestic arrangements of that large section of town dwellers who cannot run quarterly bills. Although their power of consumption is small, attempts had previously been made to extend the benefits of gas to this class of the population; but without success. Moreover, the houses were seldom piped for gas; which was regarded as a luxury of the well-to-do. The suggestion of attaching a coin-controlled delivery mechanism to a gas meter would have borne little fruit, unless the gas companies had tacked on to it a scheme for piping small houses and furnishing gas fittings, to be paid for with the gas. This system immediately took on with the public; but it was only when slot meter consumers learnt to cook by gas, and latterly to use gas fires, that this branch of custom began to pay for itself. At present, the system is generally carried out in this wise: Small householders are supplied with a slot meter, two or three lights, and a gas cooker. The premises are fitted up with these articles, and all the occupier has to do when he wants a light, or to cook, is to put a penny in the meter slot. This operation releases a valve which will close again when the covenanted quantity of gas has passed—not suddenly, but giving sufficient warning, by the lowering of the gas, that another coin is required to keep up the supply. For the extra cost of the slot meter, and to recoup the outlay on fittings, the suppliers are usually allowed by Parliament to charge 10*d*. per 1,000 cubic feet extra on the ordinary price of gas, this being the figure suggested by experience. Even so, as already stated, the slot meter department is

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not directly a source of profit. In some cases meters to take shillings are supplied to the order of customers desirous of keeping a check upon their gas consumption.

The pennyworth of gas, of course, varies in different districts; but the public do not mind that, knowing full well that at any price ruling in the United Kingdom, town gas is the cheapest and handiest domestic light and fuel for cooking. It ranges between 22 and 30 cubic feet for a penny, and the smaller quantity will

Keep an incandescent light of 60 candle power going for seven hours; equivalent to $60 \times 7 = 420$ candle hours for a penny;

or,

Cook a full dinner, comprising joint, two vegetables, and a pudding, sufficient for six persons.

The price of gas supplied through ordinary consumers' meters is always quoted in the United Kingdom at per 1,000 cubic feet, which is a convenient unit enough for account keeping, but is too large to show intelligibly the cost of the light given by a single burner over a short period. The price of gas varies, moreover, in different districts; so that there is not much guidance in working out costs upon a particular quotation. Given the quantities, it is easy to fill in local values. Neither is it the purpose of this book to compare gas lighting, in point of cost, with other means of lighting. Simple as such an operation may seem, it is by no means easy to carry out with a satisfactory degree of completeness, at least in a book intended for general consultation. Every case must be treated on its own data, having regard to the quantity of lighting required, and the local prices of the various means of satisfying the requirements. It is because of the variation of local prices of gas, oil, acetylene, and electricity, that generalisations purporting to give their comparative

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cost to the user are of so little assistance to prospective consumers, apart from the even wider variations of the prices of fittings and accessories. Besides, the choice of a lighting system often turns upon questions of taste and other considerations which override the matter of cost.

Yet the question of cost is and must remain the ultimate touchstone of popularity for every commodity and public service, subject to the pressure of competition. Sooner or later all minor differences of quality find a commercial valuation, although great inequalities cannot be compensated for in the same way. Thus, as regards artificial lights, the cheapness of oil lamps does not save them where gas or electric light are to be had. On the other hand, indirect and subsidiary recommendations must not be pressed too far in extenuation of greater costliness. The great advantage of town gaslight is, that its cheapness is not purchased at the price of any grave countervailing drawback, and goes hand-in-hand with the unlimited range of luminous intensity, which is the unique property of this illuminant.

Referring to the simple case of dining-room lighting by a single incandescent gas lamp, discussed in the preceding chapter, it is very easy to calculate the average expense of keeping such a light going for any length of time if the price of gas is known, but not otherwise. Therefore, it is quite beside the mark to talk of the comparative cost of gas and electric or any other light, as if the question admitted of a general answer; which it does not. But it is possible to say this: that for any known price of gas, the cost of any particular scheme of lighting can be exactly ascertained and adjusted. In the example in point it was found by computation that a light of 40 candle power shaded, or about 60 candle power unshaded, was required at the indicated place; and this can be had

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at the cost of the quantity of gas necessary to be consumed to produce the stated illuminating intensity, according to the known efficiency (E) of the burner selected, *plus* the cost of mantles, other accessories, and the periodical attention, cleaning, etc. Where the gas company maintain the burners, as most do if requested, the extras may amount to about 25 per cent. on the cost of the gas consumed. This principle runs right through the whole range of gas lighting, so that the expense is always in exact proportion to the service demanded and rendered; and there is no uncertainty about it. Whether the light is used for a long or a short period of the twenty-four hours makes no difference in this respect. Moreover, there are no considerations of economy to be regarded such as, with some luminants, prescribe the intensity of the unit of light. It has already been explained that the eye can do its work equally well, generally speaking, with different degrees of illumination. This is a common experience in connection with indoor lighting, a few candles scattered about a light-toned boudoir giving quite enough light for the purposes of social intercourse. Were adequate vision of minute or dark coloured objects desired, however, as in reading or sewing, it would be immediately discovered that such lighting is insufficient, unless one or two of the candles could be brought quite close to the work. But if it were attempted to hold a sewing meeting or a reading circle in the room, better lighting would be indispensable; and in the circumstances an adjournment would be voted to the dining-room, with its single powerful lamp. This is not a matter of taste, but a stern necessity. A light for working by must be sufficiently powerful for the purpose, or it is worse than useless.

This is where the advantage of gas appears most conspicuously. Users of light for a particular purpose do not naturally concern themselves about candle power, but

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FIG. 49.—A Well-lighted Druggist's Shop.

they usually know what they want. A druggist, for instance, desires to make his coloured lights shine out across the street (Fig. 49). No feeble intensity of light will serve his turn. The gas-fitter can fix him up, say six good Kern burners with reflectors behind his bottles and over his shop

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window. Two or three inverted burners over the counter, according to its length, and a double-mantle lamp at the doorway will complete the equipment of the shop. Then the normal candle power of all the burners can be summed up to serve as the standard of comparison with any other system, and the cost worked out from the local data. In no other way can such a comparison be justly made upon a light-for-light basis.

For all factories, workshops, and premises of any description needing many lights, it is money saved, as well as satisfaction assured, to have the lamps maintained by the gas company. Trouble is spared in the case of the smallest private residence by the same course; but for lighting on a large scale, not only the maintenance of the lights, but also their arrangement by the skilled officers of the gas company, or an expert lighting engineer, is greatly to the user's interest. Few persons not in the business are sufficiently expert in designing lighting installations to make a good job of it. Many examples could be given where a large sum of money has been annually saved by a skilful rearrangement of the lights of a factory, a railway station, or a warehouse. The largest railway companies, whose lighting bill is an appreciable quantity in the working charges, find that it pays to place this business in the hands of a competent lighting engineer; and most gas companies now lay themselves out to advise their customers in the same sense.

Examples of Gas Lighting.

Comparison of low and high-pressure gas lighting systems, on an estimated requirement of four high power outside lamps of 600 candle power nominal, eight ditto inside lamps, together giving 7,200 candle power, and small distributed lights giving about 4,000 candle power in the

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aggregate. Total, about 11,000 to 12,000 candle power, representing the lighting in the best possible style of a retail "stores" of considerable pretensions. The large lamps are to be self-intensifying, or Humphrey cluster lamps. Such an installation could at this date (1907) be carried out in several different styles at a first cost of about £80 for the necessary lanterns and lamps, exclusive of connections, and the gas comsumption would be after the rate of about 450 cubic feet an hour.

The same thing, in an increased-pressure system up to 15 inches of water, driven by water or gas power, could be had for about £150, with a saving of gas consumption of about 60 cubic feet per hour. A higher pressure system, up to the maximum used (52 inches), would cost about the same, and save 30 cubic feet more gas, the cost of mantles being somewhat greater. This statement will give a general idea of how the matter stands as between the different systems of improved gas lighting available for large commercial establishments.

Result of Test with Three Sugg's "Belgravia" 3-light High-Pressure Lamps, Hot-air Engine Compression, North of London, December, 1906.

Lamps.—Total working days, 27; total lighting hours, 115; average hours per day, 4¼; total consumption for period (burners only) 11,860 cubic feet; consumption per hour (three lamps) 103 cubic feet; normal efficiency as quoted by Messrs. Sugg & Co., Ltd., 31 candle power to the cubic foot; add 25 per cent. for top reflectors = E = 38 candle power to the cubic foot, below the horizontal; candle power per lamp, 1,300.

Compressor.—Total days, 27; total working hours, 153 (longer than above, owing to heating up); average number

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of hours working per day, 4 hours, 35 minutes; average consumption of bunsen burner for same per hour, 15 cubic feet.

Consumption of Bye-pass Pilot Lights.—Total days, 27; total hours alight, 648; total consumption per day (nine lights), 35·1 cubic feet; average consumption per hour, 1·46 feet (nine lights); average consumption per bye-pass light, 0·16 cubic foot per hour.

Total Cost of Gas used at 2s. 11d. per 1,000 cubic feet.

	£	*s.*	*d.*
Compressor, lamps, bye-passes . .	2	4	4
Mantles . . .		4	0
Time . . .		7	0
	£2	15	4 = 5¾*d.* per lighting hour.

Candle power per 1*d.*, including gas, time, etc., etc, high-pressure, 680.

Candle power per 1*d.*, including gas, time, etc., etc., low-pressure, 500.

Cost per hour in low-pressure, 7¾*d.*

Pressure plant cost, £37 10*s.* Lamps, £2 10*s.* each.

Some particulars of the cost of mill lighting by improved gas light have been published (1906) by Mr. A. Pollitt, in a paper read before the British Association of Textile Works Managers. Dust is the trouble in textile mills, yet by careful and regular attention (which is what is meant here by the term "maintenance"), Mr. Pollitt considers that the annual cost of an ordinary upright or inverted incandescent gas lamp, which is more than ample for two looms, will not exceed, in the North of England, 14*s.* "The best lighted workroom he had ever seen was one fitted with 43 Welsbach-Kern self-intensifying lamps of 160 candle power each—a total of 6,880 candle power for a consumption of

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323 cubic feet of gas per hour; or, with gas at 2*s*. 6*d*. per 1,000 cubic feet, 6,880 candle power at 1*s*. 8·64*d*. per hour. The area of the room was 6,030 square feet; the whole was brilliantly lighted, and the work carried on was of a most exacting character, and in all colours." To this charge for gas should be added 25 per cent. for mantles and maintenance. Taking the case of a mill requiring 20,000 candle power for 450 hours per annum, with gas at 2*s*. 6*d*. per 1,000 cubic feet, Mr. Pollitt works out the cost per hour at from 4*s*. 9·18*d*. for ordinary Welsbach burners, to 4*s*. 0·10*d*. for high-pressure gas, including interest on the cost of plant and depreciation.

Mr. Henry Fowler, the lighting engineer to the Midland Railway Company, in a communication to the Institution of Mechanical Engineers (1906) records that the cost of maintaining the incandescent gas burners on the line for the year ending June of this year, amounted to—

Mantles		5·20*d*.
Chimneys		1·27*d*.
Forks		0·33*d*.
Wages	1*s*.	4·16*d*.
	1*s*.	10·96*d*.

including indoor, station, and yard lighting.

Mr. Fowler also testifies that the change from flat-flame to incandescent gas lighting has meant for his company a saving of upwards of 43 per cent. in gas consumption, with an increase of 233 per cent. of light. He speaks well of the high-pressure lighting system in his charge, the gas consumed for compressing being only 20·8 cubic feet per 1,000 cubic feet of gas compressed. Everything included, therefore, this operation does not cost more than 1*d*. per 1,000 cubic feet. His example comprises over 300 burners,

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chiefly used to light a station by means of two-burner lamps with mantles, 13 feet above the platform, 56 feet apart. With this spacing, just over four times the height, Mr. Fowler reports a very good lighting effect, free from patchiness. As usual, the mantle consumption of burners of this type is larger than with ordinary ones, amounting under the conditions of a railway station to 8—10 mantles per annum. For such interiors as parcel offices, Mr. Fowler finds an illumination varying from 0·9 of a foot candle on the floor sufficient. This is obtained by 3-light C burner pendants under a 28-inch enamelled reflector. For lighting goods yards, 3-light incandescent lamps on posts 100 feet apart, are found satisfactory. Inside goods sheds the spacing is reduced to 30 or 40 feet, with lights 11 to 13 feet above the platform. Mr. Fowler's use of large whitewashed reflecting boards, or false ceilings, to improve the illumination of glass-roofed workshops has already been noticed. The problem here was first presented in the shape of a locomotive erecting shop, which needed a good general well-diffused light from sources high enough to clear the travelling cranes, 29 feet above the floor level. In this case clusters of three burners, each consuming 10 cubic feet of gas per hour, with pressure increased by water-power to 8 inches, are suspended at a height of 30 feet 6 inches above the floor underneath whitewashed boards measuring about 10 feet square. The illumination, 29 feet 8 inches below the burners, varies from 0·8 to 1·4 feet-candles. The burners only require attention once a week.

(This method of lighting indirectly, by reflection from a dead white surface, gives pleasing results in numerous cases, especially for lighting pictures, drawing schools, museums, etc. The lamps themselves, of course, must be screened from view. The quality of light thus produced is shadowless, and free from mirror-like scintillations.)

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Foundries and fitting shops can be satisfactorily lighted in the same fashion; but where there is much belting the lamps must be brought nearer the tools, in which case reflector lanterns are necessary. Where the mantle consumption is excessive on account of vibration, anti-vibrators, of which there are many patterns to choose from, must be used.

An exhaustive paper, describing the "Selas" system of lighting by mechanically mixed gas and air, was contributed to the Institution of Gas Engineers in 1903 (*vide* "Transactions") by Mr. F. D. Marshall. This system was first developed on the Continent, as an improvement on ordinary low-pressure Welsbach lighting, chiefly for mills and factories. Figures are given in the paper showing that by the adoption of this system the gas consumption of certain cloth calendering mills was reduced from £130 to £77 per annum, with a large increase of light. In other cases, of hotels and cafés, the gas bills have been reduced by one-half or more, by the same means.

In an arsenal workshop, with a ground space of 22,500 feet super, high-pressure incandescent gas lighting at 52 inches of water, on the Sale-Onslow system, was introduced to light 250 men at bench work, the belting being very obstructive. Sixty 400 candle power lamps are installed, 8 feet 6 inches above the floor. The actual cost per hour is given as—

	s.	*d.*
Gas (at 2*s.* 6*d.* per 1,000 cubic feet) .	2	1·2
Wages		6·0
Mantles		6·0
Depreciation, 10 per cent. and interest 5 per cent. on first cost		8·6
	3*s.*	9·8*d.*

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FIG. 50.—An example of modern gas lighting. The new Victoria Station, L. B. & S. C. Railway, London

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or 0.18*d*. per hour per man during the lighting hours, taken at 1,000 per annum. The shop is lighted like day. All lamps are hung on spiral springs, as the shaking and concussion from gun fire are considerable.

One of the best displays of high-power incandescent gas lighting in existence is that of the new Victoria Station of the London, Brighton, and South Coast Railway (Figs. 50 and 51). The company had had previous experience of the economy and efficiency of incandescent gas lighting, at the ordinary pressure, in their old Victoria Station; and the knowledge that the efficiency of gas is doubled by increasing the pressure to 50 inches of water, decided them to adopt it for the new station. This installation comprises 400 lamps, varying from 175 to 1,000 candle power, which are supplied with gas at a pressure of 50 inches from two Sale-Onslow compressors, the power plant being duplicated throughout for safety. The platforms are lighted by Sugg's "Chertsey" pattern lamps of 350 candle power, except those on either side of the carriage drive, which are lighted by lamps of 500 candle power, spaced about 50 feet apart, the lights being about 12 feet above the platform level. The station yard is lighted by "Belgravia" pattern lamps of 1,000 candle power, 25 feet and 30 feet high.

With respect to the economy of incandescent gas lights in the public streets, sufficient proof of the fact is furnished by the action of the South Metropolitan Gas Company, who in 1901 reorganised the public street lighting throughout South London, providing new and improved lamp-posts and lanterns of an elegant pattern, and paying themselves by the saving in gas over the old flat-flame system, spread over a term of years. The local authorities and the public thereby at once entered upon the enjoyment of the improved lighting, without extra charge.

Many special installations of high-power incandescent

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Fig. 51.—The platforms in the New Victoria Station, L. B. & S. C. Railway, London (Sale-Onslow high-pressure light).

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gas lighting are in operation in all the principal cities of the civilized world, and it would be over-loading this book to give details of their cost, which can easily be obtained locally by interested persons. So much, in making up a statement of this character, depends upon such particular considerations as the expense of breaking open the roads, running the necessary connections, etc., that the actual cost is seldom of general applicability. Only one typical example will therefore be described here. It is that of the lighting of the new London thoroughfare called Aldwych and Kingsway, for which gas was chosen after careful investigation. This case illustrates what has been pointed out as governing the selection of a high-pressure system of illumination, namely, the width of the road, which is 104 feet between the frontages, and 60 feet between the curbs. The lights are placed along the curb line, with additional refuge lamps at the crossings. The total length of Kingsway and Aldwych is 3,620 feet, and in it there are 51 lamps, which gives 71 feet spacing. The lamps are 21 feet above the pavement; the lanterns are 33-inch, circular, with two burners, and the enamelled steel top-reflector is slightly convex, which diffuses the light afar. The contract illuminating power of each unit is 700 candles, but actually they are of about 1,000 candle power. The installation cost was £20 per lamp, repaid in five equal instalments. The annual charge for gas (at 2*s*. 3*d*. per 1,000 cubic feet) and maintenance is £15 0*s*. 11*d*. per lamp, subject to an increase or decrease of 9*s*. 6*d*. for every penny per 1,000 cubic feet increase or decrease in the price of gas for the time being. The compressing plant is on the "Millennium" system, driven by a gas engine. It is placed in a neighbouring cellar. All the lights are fitted with automatic high-pressure bye-pass and pilot flames, by which means they light up simultaneously on the starting

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of the compression plant. The lighting hours are 3,940 per annum, and the full light is given all the time.

It should be noted that with all high-pressure gas lighting systems, the worst that can happen in case of a complete breakdown of the pressure plant (which is always provided against in important installations by duplication) is the sinking of the lights to the lower efficiency of the ordinary main pressure. In no case is extinction of the light from this cause to be feared.

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CHAPTER VII.

HEATING AND WARMING BY GAS.

Original utilisation of the warmth of burning gas—Flueless heating stoves—Gas "fires"—Comparison with domestic coal fires—The question of expense—The "fire in the grate"—The self-contained fire—Efficiency tests—The heating of water for domestic purposes—The combination of coke and gas in domestic service—Gas as an industrial fuel—High-pressure gas furnaces.

THE general use of town gas as fuel for domestic and industrial purposes is a practice which cannot be dated much farther back than the Crystal Palace Electric and Gas Exhibition of 1882. At that period it was still doubtful whether the greater expense of gas in comparison with coal as applied to the purpose of warming living rooms, left much opportunity for developing the former in this direction. The warmth of gas when burnt for the purpose of lighting, was also regarded by the general public with mingled feelings. The large consumption of gas necessitated by the imperfect burners of that day if a brilliant scale of lighting was desired, frequently produced over-heating of small or crowded rooms; and in such cases the warmth produced by the gas was found objectionable. On the other hand, the same incidental effect was appreciated in winter by workers in shops, factories, and warehouses not provided with other means of warming. Consequently, whenever the weather turned cold a great deal of gas was, and still is, burnt for the sake of the incidental cosiness and brightness of it, although not by means of regular warming appliances. It

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is largely for this reason that cold weather is even better than fog for promoting gas consumption, from the gas company's point of view, although the warmth given off by incandescent gas light is only a very small fraction, for the same scale of illumination, of that produced by flat-flame burners.

It is safe to say, therefore, that the idea of using gas for warming interiors originated with its use for lighting them, and, in fact, the earliest gas-heating appliances put upon the market were no more than ordinary illuminating burners enclosed in casings, for safety, and made to be fixed on the floor. Many varieties of such appliances are still on the market, and in great demand, because they fill a place that would otherwise be void. They do not require a flue-connection, which does not exist in many retail shops, warerooms, printing offices, and the greater number of small counting houses, waiting-rooms, and so forth, which the necessities of modern business life require to be occupied by sedentary workers. The same demand arises for warming churches, corridors, landings, small entrance-halls, etc., which are without fire-places. The solution of the practical difficulty of providing a comfortable degree of warmth in interiors presenting such conditions, lies in the selection of a suitable flueless gas-heating apparatus. These appliances are the most economical warming agencies available, with the exception of mineral oil lamps, which have their merits for the same use, but are subject to the disadvantage of requiring too particular attention for any but strictly private premises. This superior economy is due to the circumstance that the whole of the heat of the fuel consumed is utilized, the radiant heat of the flame, as well as the heat of the combustion products, being obtained in the apartment. Thus a very small gas consumption in a so-called stove of this kind goes a long way in taking off

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the chilliness and "raw" feeling from the air of a room, precisely as though the same gas had been burnt for the sake of its light. Nor can the gas flames, when used for heating, and therefore placed near the floor, possibly be more harmful as regards vitiating the air, than when fixed overhead, to give light. In both cases, the ordinary ventilation of the apartment, the continual opening of doors and the movement of people in shops, corridors, etc., usually provides more circulation of air than is necessary to health.

Starting, therefore, with flueless gas-heating apparatus, as coming first in the natural order, the user has a choice of numerous simple styles of gas-warming appliances, which consist essentially of a number of luminous gas burners, screened from view for the simple reason that one does not want bright light at the floor level, whose radiant heat is reflected out into the room by sheet copper. These little stoves can be placed anywhere out of the way, and they answer the purpose quite well for rooms up to 12 feet square, burning about 8 cubic feet of gas per hour when turned on full.

FIG. 52.—Gas Steam Radiator.

The latest thing in flueless gas-heating arrangements are "steam radiators," which are made on the well-known pattern of such warming appliances when supplied with boiler steam (Fig. 52). They are sold in several sizes, and

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with any number of "loops," and are effective and economical. Even the largest sizes used for workshops or stores do not consume as much gas per hour as an old-fashioned 5-light "chandelier," while the small sizes, just high enough to stand against the wall beneath a window, only burn 8 cubic feet of gas an hour, for a rated heating capacity of about 1,200 cubic feet of space. The principle of action of these appliances is that of continuous steam generation and condensation, from a small quantity of water contained in the bottom of the enclosed system of tubes. The steam pressure is very low, and safety is assured in the usual way by a weighted valve. The extent of the radiating and cooling surface is so much greater than that of the heating surface, however, that even without a valve the steam pressure could not attain a dangerous amount. A thermostatic gas valve, moreover, always tends to shut off the supply to the burner if the heat rises too much. A handy green-house or garage warming apparatus is also illustated (Fig. 53).

Although flueless gas-warming stoves consume so little gas that they cannot possibly vitiate the air of a closed apartment more than the illuminating burners, whether of gas or oil, that have been used by everybody for the last two or three generations with no traceable ill-effects, yet they are not recommended for sleeping apartments, simply because they act chiefly by warming the air. This is not in accordance with the dictates of medical science, which forbids the breathing of anything but the freshest air during sleep. Therefore, heating by radiation (which does not directly warm the atmosphere) is to be preferred wherever the existence of a chimney renders a radiant fire possible. Besides, after all is said and done in this connection, the British fire in its open grate is the pleasantest [illegible] way of warming a living room in [illegible] chan[illegible]

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climate, which rarely brings cold sharp or prolonged enough to call for the more powerful, but stuffy, heating methods necessary in corresponding or higher Continental and American latitudes.

Regarded solely as a consumer of fuel at the usually quoted prices, the common coal fire looks undoubtedly less expensive than the copy of it in which gas is burnt to heat up refractory material to a point of effective radiation. Obviously, the crude comparison of prime cost here is between a raw material and a pure product manufactured from it. More important still, it is a comparison, as usually stated, between the price of coal dumped into the household cellar, and of gas delivered at the point of consumption. This is to overlook a most important element of expense to the householder in the former case. For example, a small middle-class family living in the Home Counties, will burn in winter, for warmth alone, a ton of coals per month, costing, say, 25*s.* delivered. This also entails the hire of one maid servant, costing, with board and lodging, £4 a month. Kindling-wood, chimney sweeping, damage by smoke and dirt, are difficult to appraise in figures, but they all cost money. Reckon the extras at 10*s.* per month.

FIG. 53.—Greenhouse Heater.

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This computation brings up the cost of the coal *actually in the grate* to £5 15*s*. per ton. D. Kinnear Clark, testing grates and stoves for the Smoke Abatement Society, found the grates burnt on an average 3·65 lbs. of Wallsend coal per hour, which maintained a room temperature at nearly 11° F. above the outside air. The consumption of gas to do the same work would be about 30 cubic feet per hour, in a properly constructed "fire." In a long day, therefore, from 8 a.m. to 10 p.m. (allowing 2 hours more for the coal fire to light up and die down) the consumption of fuel in each case would be as follows:—

Coal, rather over ½ cwt., at 115*s*. per ton, inclusive of house labour and other extras, 2*s*. 10½*d*.

Gas, 420 cubic feet, at 3*s*. per 1,000 cubic feet, 1*s*. 2¾*d*.

Usually, however, a smaller coal fire than the above[1] would be found burning, as incessant attention would be required to keep up such a regular blaze. This, indeed, is one of the familiar drawbacks of the coal fire, to be regarded as a set-off to the reputed pleasure of poking it, and the very real companionableness of a bright fire when one has leisure to sit and gaze at it. The latter consideration is

[1] The following particulars of a special test made by the author tend to elucidate this point. It was ascertained that with an outside temperature of 45° F., in January, the weather being dull, calm, bar. 30·6 ins., a ground-floor room of about 2,000 cubic feet capacity, with a large front window of five sashes (one open at the top 9 ins.) and door frequently opened—the ordinary conditions of occupation, in brief—was kept at an even temperature of 60° F., as marked by a thermometer on the wall, four feet from the floor, by a fire in a canopied grate, consuming 2 lbs. of coal per hour. In the case of a *single* coal fire in the house, no extra cost for domestic labour can be fairly imputed. Hence the cost of this fire is only that of the coal and wood. The consumption being about ¼ cwt. per day, the total cost is not more than 6*d*. The habitual use of more than one fire, however, would certainly entail additional service, the cost of which should be taken into account.

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worthy of all respect, but how much of the ordinary use of a fire does it represent? As Dr. Des Vœux said at the Smoke Abatement Conference of 1905: "There is no pleasanter sensation than the sight of a bright, burning coal fire when we enter a room cold and tired. But what about the same fire which the housemaid has allowed almost to go out, and buried the burning coals with five or six inches of fresh fuel!" In point of fact, the same speaker told the Sanitary Institute, at a meeting in December, 1906, that he had for this and other good and sufficient reasons, given up the coal fire in his own rooms, finding it much more satisfactory to light up a gas fire when returning at all hours, perhaps cold and wet, from a professional visit. In ten minutes the craved-for comfort is in full swing (Fig. 54).

FIG. 54.—A Self-contained Gas "Fire."

Dealing with the same aspect of the warming problem, the reporters on gas fires to the Coal Smoke Abatement Society, referring to a series of tests conducted early in 1906, and recorded in the *Lancet* for November 17th, 1906, observe that the gas fires produced their effect much more quickly than coal fires. It was also noted that the curves of rising temperature for the gas fires are much more even and show a more regular rise, which is explainable by the irregular making up of the coal fires. "Another point in favour of the gas fires is that they can be easily regulated, and the heat of the room controlled in a way which is not possible with coal fires." The waste involved in the

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burning-up and dying-down of the coal fires is also against their economy. And when once lit up, the coal fire must be kept going whether really wanted or not, which is not the case with gas. The labour and other incidental costs and considerations attaching to a coal fire are the same whether it is in use for an hour or a whole day. This fact, in households where economy of money and labour has to be studied, often means going without the comfort of a fire altogether. It may seem an extreme statement in this connection to charge the whole expense of an extra domestic servant to the fires alone, seeing that this work does not occupy the whole of the domestic's time. Yet, in practice, the fact remains that in households which can do with one servant during the summer, the season of fires does call for additional help which would not otherwise be needed.

Therefore, taking everything into consideration, even where some fires are wanted all day, there is little to choose between the expense of coal and gas of equal heating power, to say nothing of the additional recommendation of the latter that it will usually cause less draughts than the former. For temporary, occasional, or sick-room use, however, there is no question of the advantage of gas. The comfort of a fire to dress or undress by can by this means be had for at most a penny a time. Chilly mornings and evenings of bright autumn and spring days can be made cosy in the same way. The economy and convenience of this means of warming offices, consulting rooms, etc., cannot be disputed.

The most satisfactory kind of gas "fire," when taken to permanently, is one that is made up by an experienced workman in the grate itself. This expedient is to be recommended where the grate is of a good pattern, set in a chimney-piece to correspond. There is then no clashing of designs between the fixed fireplace and the structure of the

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ready-made "gas fire," and the adaptation of the grate to gas firing need not affect the scheme of decoration. The adaptation consists in filling in the grate with the heat-radiating material, which is formed in irregular honey-combed pieces, the back of the grate being also brought forward with special fireclay blocking. The bunsen burners are placed underneath the so-called "fuel," which they should quickly raise to a bright incandescence without causing any smell. Where the grate is large, a double tap should be fixed as near it as can be contrived, by which the fire can be turned "full on," "half," or "off." A second tap, or valve, at the point of connection between the iron piping under the floor and the brass tubing led round the fireplace to the grate, is an additional security, and also enables the gas pressure to be regulated so as to produce a silent flame. This style of fitting should always be insisted upon. Everything included (from the iron piping near the fireplace, supposed to be already in place), the usual charge for fitting up a gas fire in the grate is not more than 25*s*. The average consumption of gas in a 17-inch grate at a fairly good pressure will be 35 to 40 cubic feet per hour "full on," reduced to 25 or 27 cubic feet per hour at "half," which can be done after the first hour or two, according to the degree of warmth desired. A room of 2,250 cubic feet capacity can have its temperature raised to 13° F. above the outer air (at 45°, calm) in two hours by this means, and this temperature afterwards maintained with the "half" fire. Moreover, the fire itself will be giving out its full radiant heat, and therefore yielding a comfortable sensation in less than a quarter-of-an-hour from lighting. The radiant effect of such a fire is quite equal to that of a bright coal fire about half-filling a grate of the same size and style—that is, about the same fire that would be kept up during such weather, cool, but not cold.

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Winter in the South of England has a majority of such days.

The gas fire "in the grate" is favoured by medical men for their own use, and is recommended by them chiefly because it does not interfere with the ordinary ventilation of the room by the chimney. Its action precisely resembles that of a coal fire, with the advantages of quietness, steadiness, and less draughtiness. A window should always be left slightly open with gas fires, which will obviate any feeling of dryness due to the regularity of the heating, which in this respect tends to resemble stove warmth.

Gas fires ready made up into an infinite number and variety of patterns, sizes, and powers, are on the market, and can usually be hired at low rates from the gas company, who will also fit them in place at the cost price of the materials and labour. Suitable specimens can be selected to suit most fireplaces or to supplant an ugly, wasteful, "sham register" grate, and the sizes are conveniently adjusted to the requirements of different apartments. Although quite self-contained, these appliances should be fixed by experienced workmen, as difficulties occasionally arise with respect to the chimney draught, gas pressure, and other details which require adjustment. The gas-fitter should always be asked to show those who will have the use and care of gas apparatus how to light the burners, and what to do in the event of atmospheric burners "lighting back," or giving trouble in any other way (which is rare).

Small, neat gas fires, quite powerful enough for any apartment up to 11 feet square, or a bath-room, can be had to burn not more than 13 to 15 cubic feet of gas per hour. For bedrooms and nurseries, patterns are supplied with a convenient boiling burner on the top, which is much appreciated.

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The following particulars of the performance of a 9-inch bedroom gas fire are authentic. The apparatus was fixed in front of the fire grate (the front bars being removed) with sheet-iron blocking the open chimney throat, through which passed the 3-inch flue-pipe, a 2-foot length inside pointing up the chimney to ensure an adequate draught. The room is on the first floor, with a capacity of 2,070 cubic feet. Almost the whole extent of the front wall is window, there being six sashes in all, ill-fitting, and one of the top sashes is always 9 inches down. At 9.30 a.m., with the outside air at 34°, air calm and misty, the temperature in the room, 4 feet from the floor, on the wall facing the window, was 45° dry bulb, 43° wet bulb. The gas was lighted (the room being vacated), and in ten minutes the occupant returning from his bath would find a glowing fire already making a warm spot on the floor. At 10 o'clock the room temperature had risen to 48^{c}, and continued to rise until 11.30, when it was 52° dry bulb and 49° wet bulb, thus still showing 80 per cent. humidity. The room door had been thrown open and the housemaid's work carried on meanwhile without interfering with the warming process. As the temperature attained was considered high enough for a sleeping apartment, at 10.45 the supply of gas, which had previously been at the full burning rate of the fire, 22 cubic feet per hour (as shown by the flame slightly tailing above the "fuel"), was reduced by the regulating valve to 17½ cubic feet per hour. With this quantity of gas the bedroom temperature was maintained throughout the day at the figures above stated, there being not the faintest odour from the stove, and the room feeling both fresh and comfortable when entered, especially by contrast with the dank, chilly, and gloomy weather outside. If a higher temperature had been wished, it could have been obtained for a very small increase of gas consumption

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—merely, in fact, turning up the flame to the fu capacity of the apparatus, about 22 cubic feet The radiant effect of this gas fire was about 2 less than that of the 17-inch fire in grate alre tioned as burning twice as much gas. (Later, having become very thick, the window was closed, w the temperature of the room rose to 54°.)

In a small bedroom, of 1,340 cubic feet conte fire burning 15 cubic feet per hour quickly ra

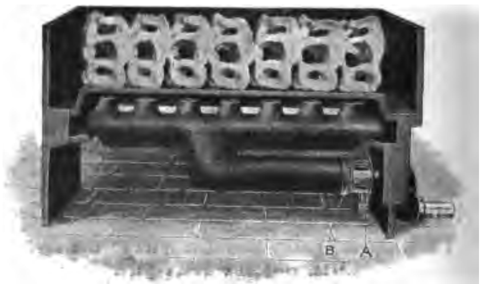

FIG. 55.—Showing how the "fuel" should be packed over the gas burners (like a chimney for each flame); also air (B) and gas (A) adjustment.

temperature from 46° to 54°, with an outside temp of 35°. The radiant heat in front of the fire was e that of an ordinary coal fire in a grate of the san The same comfortable warmth was maintained afte with the gas consumption reduced to 13 cubic feet per

In all gas-heating appliances in which the bunsen is used, care should be exercised by the makers and to see that the flame is allowed adequate space in to burn itself out (Fig. 55). Nothing solid, as "fuel" of gas fires, must be allowed to come in the w the flame until at least the primary combustion is com

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The next domestic boon available by the consumer of town gas is the provision of a hot bath, or supply of hot water generally, at short notice, at any hour of the day or night. The apparatus first successfully employed for this purpose was called a "geyser" by the makers; and various patterns of water-heating appliances of this type have come into extensive use, especially to supply the deficiency of the now indispensable circulating hot water supply in old houses (Fig. 57). They all possess the common character of a "coffee-pot" form of vessel, inside which very powerful gas burners are caused to play upon metallic containers of the water to be heated, so constructed and shaped as to present the largest possible wetted area to the heat. Inasmuch as flowing water is very difficult to heat on its course, a large quantity of gas is required to be burnt in all geysers which conform to the principle of water flowing in cold at one end, and coming out hot at the other. The hotter the water is required to be, the greater the work to be done in satisfactorily heating it in a short period of time. Modern patterns of the "geyser" conform to all the conditions of safety in use. Combination taps are fitted to them to prevent the gas being on unless water is running through the apparatus; the lighting of the battery of burners is made simple and safe; proper flue connection is provided and made effective. The last is the most essential point when the geyser is fixed in the bathroom. A good, reliable chimney draught is *absolutely necessary* to carry off the large volume of combustion products from the powerful burners used. Merely knocking a hole in the wall and putting out a flue-pipe is seldom satisfactory. If no effective flue connection can be contrived, the geyser may be fixed in an airy passage *outside* the bathroom, where there is usually sufficient circulation of the air to enable a chimney on the apparatus to be dispensed with. They are made

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self-acting, so that hot water flows on opening a tap. The efficiency of good apparatus of this class is very high, attaining 93 per cent., that is to say, a modern geyser will realise in the temperature of the water passing through it

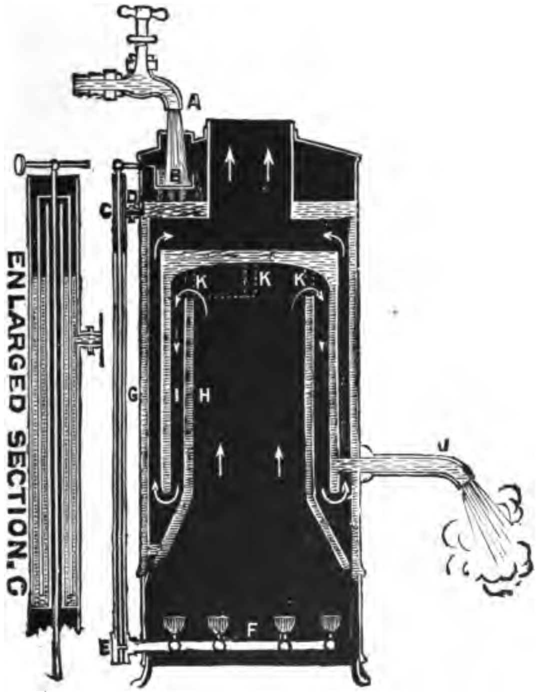

FIG. 58.—Interior of the Geyser.

this proportion of the calorimetric heating power of the gas burnt.

Some low-priced geysers heat the water by direct contact with the products of combustion of the gas. The water in this case is never raised to a higher temperature than 130° to 140°, and is unfit for drinking. It is necessary

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also that the apparatus should be placed at a superior level to the point of discharge of the warm water (Fig. 58).

Another class of water-heating appliances for the household comprises circulating heaters, which work under pressure, and can therefore be fixed in any position *below*

Fig. 59.—Hot Water Circulator.

the point of discharge. That is to say, they are complete substitutes for the ordinary circulating kitchen-range boiler, being similarly constituted of a boiler in a close pipe system, with a cistern for accumulating the warmed water, which is gradually heated by returning continuously through the boiler. Such an arrangement can easily be installed in any "flow and return" pipe system, at a

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convenient point, which will usually be in the kitchen, where it can be attended to. This method of heating bath and washing-up water by gas is not of the "instantaneous" order, and is distinctly economical of gas (Fig. 59). It does not interfere with the use of the coal fire circulating boiler, to which it may be regarded as an accessory. It obviates the common necessity of lighting the kitchener fire merely for the sake of having a bath. The burners are double, one being quite small, for use during the night in cold weather to prevent freezing of the pipes; the other a powerful one, capable of providing a hot bath at short notice. The consumption of about 50 cubic feet of gas will give a full bath of 50 gallons of hot water. If fixed in the kitchen, connection with the chimney flue is not necessary, owing to the small gas consumption, but is always desirable. When regularly used, with the small burner only alight, all the hot water required for the work of a house can be had at a cost of under 3½*d.* per day, with gas at 3*s.* per 1,000 cubic feet. (The quantity of hot water used in a house occupied by a family of five persons for ordinary sink and lavatory purposes averages about 20 to 25 gallons. There is no call for the circulation of *boiling* water) (Fig. 60.)

FIG. 60.—Gas-Heated Boiler.

The gas consumption by an apparatus of this class should be adjusted to raise the water stored in the warm cistern

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to not exceeding 120°, when there should be no choking of the pipes with hard scale.

In large town houses, where gas cooking is practised, and the additional requirements of a plentiful supply of hot water and heat in the kitchen, for airing clothes, etc., are imperative, the most economical and efficient arrangement is a coke-fired boiler, installed alongside the gas kitchener in the wide fireplace. Dr. Des Vœux said at the Smoke Abatement Conference in December, 1905, "Eight years ago I installed a coke boiler, and each year I am more satisfied with it. It has given a magnificent hot-water supply throughout the house at a temperature of about 170° F., and the supply has been so plentiful that I have been enabled to put on three hot-water radiators into passages. The cost of this system is from 1*s.* 3*d.* to 2*s.* a week, depending mostly on the price of coke. With a gas cooker and a coke boiler, the difficulties of a hot-water system and the warmth of the kitchen are surmounted. If this system was installed in all the houses in London, the greater part of the smoke from private houses would be prevented. I myself have gas fires in my bedrooms."

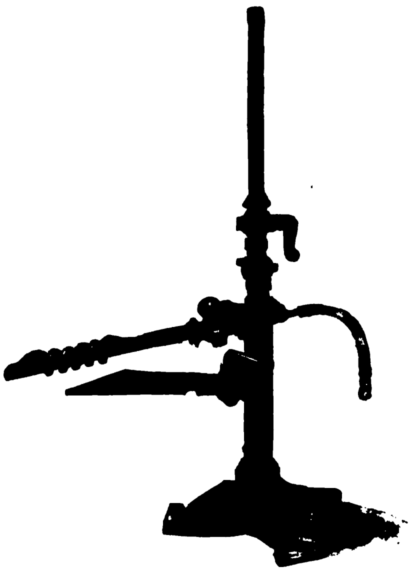

FIG. 61.—Gas Blowpipe.

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The trade and industrial applications of town gas for heating are "legion." Its greatest and most obvious recommendations in this connection are its cleanliness and handiness. Every good business man weighs all his expenses and cares against his output, and directs his

FIG. 62.—Laundry Iron Heater.

manufacturing methods along lines of least resistance. For this reason, he is not misled by comparisons of the cost of gas as fuel, at the tap, with that of coal in the store. The burning of coal means attention, labour, dirt, smoke, and ashes to clean away. Town gas means none of these things. There are very few manufacturing operations conducted in town factories and workshops,

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from the reduction and tempering of metals, down to the soldering of stained glass windows and the ironing of hats,

FIG. 63.—Soldering Iron Heater.

for which gas is not the most convenient fuel. This fact is being recognised more widely every day. There are, for

FIG. 64.—Safety Glue Pot Heater.

instance, a vast number and variety of constructively dangerous trades, which constitute the quarters where they are carried on veritable danger spots from the point of view

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of the fire insurance offices, which either decline business in these regions, or only take the risks at exorbitant premiums. These include all the trades which use glue-pots, hot varnishes, hot irons (not laundries), and tools and processes of this character. Often the crudest appliances, dating

FIG. 65.—Crucible Heater (normal pressure).

from a former stage of business, still linger in this class of factories, whereas every prudential consideration points to the exclusive use of gas for fuel (Figs. 62, 63, 64, 65, 66).

Gas heating is indicated for all purposes necessitating a regular and unvarying temperature, as for bottling-cellars, etc. This requirement can sometimes be met by a simple arrangement of ordinary flat-flame lighting burners, which are really the most effective gas-heating appliances

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that can be had, wherever they are otherwise admissible, as they give up to the air of the room all the heat contained in the gas, and are susceptible of perfect regulation by a workman.

The warm air arising from gas flames, however, including that produced by all "flue-less" gas stoves, is moist, and is therefore inappropriate for any purpose requiring dry warmth. Such interiors, of which motor garages, furniture warehouses, hardware stores, bedding emporiums, etc., which only require the chill to be taken off the air and the

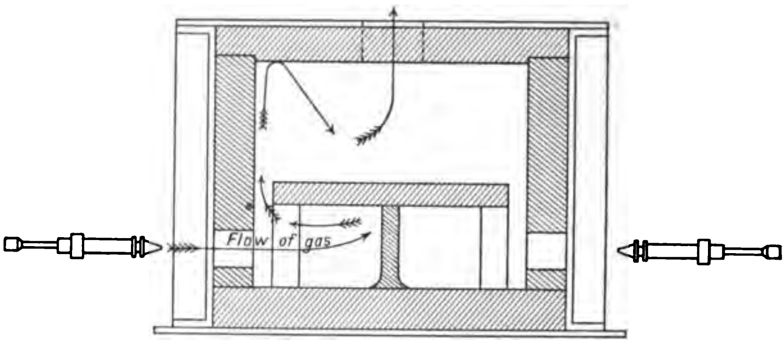

FIG. 66.—High-pressure Coal Furnace for Crucibles.

deposition of damp prevented are examples, can be safely and economically fitted with ordinary flow-and-return warm water pipes, kept at a gentle heat day and night, without attention, by one of the circulating water heaters already described, fixed in a convenient place with a proper flue.

Apart from ordinary temperature requirements of heating arrangements and dispositions, which practically suggest themselves to anyone acquainted with the properties of gas as ordinarily supplied, and can be met by stock apparatus, there is an important and growing application to industrial purposes of high-pressure gas heating. This has grown

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out of the development of high-pressure gas-lighting, and is worked by the same simple mechanism. By means of town gas raised to 60 inches or 100 inches of water-pressure—which is easily effected by a gas engine and pump—highly refractory metals, such as platinum and its congeners, can be fused, and the most refractory kinds of glass and ceramics manufactured. Considerable weights of

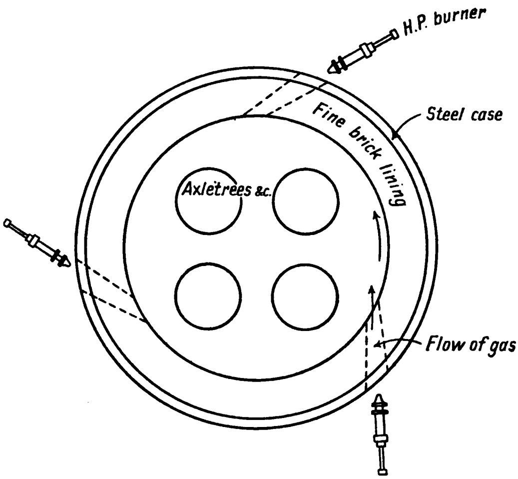

FIG. 67.—High-pressure Gas-annealing Furnace.

steel, in the form of axles, can also be quickly tempered by the same agency; and wheel tires and gun rings "shrunk on" with great saving of time and money. All varieties of welding, brazing, and case-hardening work can be expeditiously done by the same means. Also the melting of the stereo-metal for printing presses. This particular use of town gas is, indeed, yet in the early stages; and it is impossible to anticipate the advantages which its high flame temperature and constant composition may have in store

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for the manufacturing industries requiring the highest class of clean gaseous fuel (Figs. 66 and 67).

Although somewhat expensive in this connection, town gas is used to a considerable extent for raising steam in comparatively small units and for special purposes in town factories. Its great recommendation here is its cleanliness, it being possible to have the steam boiler inside the building where the work is going on, thus also saving valuable space. High-power burners are specially made for this purpose, and in respect to this and other peculiar demands for gas heat, the user is advised to consult the makers of gas appliances on a large scale, as the necessary apparatus is not made for stock. Indeed, many of the fuel uses of gas are of the nature of trade secrets, and the designs are not published.

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CHAPTER VIII.

COOKING BY GAS.

General advantages of the use of gas for cooking—A contribution to the solution of the "servant question"—The hygiene of gas cookery—General description of gas cookers—Saving of time by their use—The placing and management of gas cookers—Hints and cautions—Special gas cooking appliances—Coffee roasting; cutting-up tables, etc.—The cost of boiling water by gas—Gas baths.

THE use of gas for cooking is very general, on account of its superior convenience and saving of labour. The question of the cost of the fuel is of no importance when set against the other considerations in favour of cooking by gas, whether on the largest catering scale or by a single person having his or her own meals to prepare; although, as a matter of fact, gas comes cheaper than coal in the ordinary way. This use of gas is only a very little older than that of gas heating, having been first rendered commercially and domestically practicable between the years 1880—85, when British gas companies undertook the development of gas cooking stoves in connection with the hiring-out system. Previously to that epoch, apparatus for cooking by gas was of a cheap and perishable order, or was limited to boiling burners intended for occasional use. In good kitchens, however, and by professed cooks, the merits of gas for stewing and simmering and sugar boiling were already well understood and appreciated. The circumstance of dwelling-houses in England being provided with cooking ranges by the landlord, formed an obstacle to

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the substantial improvement of gas cookers, few tenant occupiers caring to spend much money upon such articles, even if they had been in the market. It was only, therefore, when the gas companies—particularly the large London undertakings—definitely adopted the plan of hiring out approved gas cooking stoves that manufacturing skill and enterprise turned into this channel, and produced goods equal in efficiency and durability, while surpassing in convenience, the familiar close fire kitchener. Even then much had to be accomplished by way of exhibitions and demonstrations before the public at large took to gas cooking; but the vogue once created, has never suffered a check, household workers being persuaded of its labour-saving merit. The great and ever-deepening "servant question" of middle-class households has proved a strong incentive to the popularity of gas cookers, whilst they have excelled the sewing machine in sparing the strength and saving the time of the army of housewives who "do their own work." Lastly, the placing of gas cooking stoves at the command of the humblest housekeepers, by the agency of the slot meter, has ameliorated the home life of thousands.

The opinions of Dr. Des Vœux on gas fires have been quoted in the preceding chapter; and he is equally worth quoting on gas cooking, which he practices as well as recommends. Referring to the case of a young teacher who confessed to often going supperless to bed rather than be at the trouble of lighting a fire to cook with, he advised gas, and received a letter in which the following passage occurs: "I thank you for all your kindness in advising me to have gas in my little flat. Although it is a penny-in-the-slot, it works marvellously. It is really a great comfort and economy, and it is so clean! I find it much cheaper than coal, costing me on an average 1*s.* 2*d.* a week, against 1*s.* 8*d.* for coal; and now I do not know what I should do

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without it." This naive confession sums up the popular case for gas cooking. People now will not do without it. Houses will not let, and young domestic servants refuse situations where there is no gas. The interest of sanitarians on the same side is enlisted by the consideration that every gas stove in regular use means one smoky chimney the less. Already the progress made in this direction is considerable. During the ten years ending 1905, about a million gas stoves of all sizes came into use in London and the twenty largest towns of the United Kingdom. There is no valid reason why this process should not go on until British cities become practically smokeless, at least in summer.

Gas cooking apparatus can be had in great variety, from the simple boiling ring, costing a shilling, and quite suitable for preparing a bachelor meal of fry, tea, and toast, to the large appliances used in hospitals and by the chief caterers for roasting and baking by the hundredweight. An idea once prevailed, like that which long ago prejudiced our ancestors against coal kitcheners, that food cooked by gas must taste of it. Of course, gas itself never comes into contact with the viands; and the heat of purified gas must be purer, if possible, than that from coal.

On this head the testimony of *The Lancet* should be conclusive:—"The question narrows down to a consideration of the effects which the products of gas combustion, whether they be complete or incomplete, are likely to have upon the meat. We may thus count upon the exposure of the meat to small quantities of such incomplete products of combustion as carbon monoxide, acetylene and sulphurous acid, and to the complete products, carbon dioxide, steam, and traces of sulphuric acid. It is well known that during the cooking of meat by whatsoever process the meat loses weight, or, in other words, there is a constant emission of

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vapour, and, consequently, it can hardly be supposed that absorption can be going on at the same time. But assuming that not to be the case, what effects is the bombardment of small quantities of carbon monoxide, acetylene and sulphurous acid likely to have on meat, and would these effects render the meat less suitable for food? Both carbon monoxide and acetylene form molecular combinations with the colouring matter of the blood, but then at the high temperature of the cooking process it is hardly conceivable that such a combination could take place, besides which a plentiful supply of air would prevent either carbon monoxide or acetylene from being permanently absorbed. The minute quantity of sulphurous acid would tend to bleach the colour of the meat, but as a rule no effect of this kind is observed. If sulphuric acid is formed, this, at a high temperature, might possibly char slightly the surface of the joint. All such speculations, however, are strongly discounted by the fact that meat during its cooking is emissive and not absorptive. As to steam and carbonic acid, it is questionable whether they could have any depreciatory chemical action at all. The conclusion seems inevitable, therefore, that any differences that are shown between meat cooked in front of the fire or in an oven next to the fire, and meat cooked in a chamber containing gas flames inside, must be due entirely to physical and not to chemical causes. In a word, the explanation must lie in the different manner in which the heat is applied in the different circumstances. It should be borne in mind, however, that in cooking by gas the meat is exposed to a rapid current of steam derived from the combustion of the gas, whereas in the range oven the only steam present is that which comes from the meat itself, while in open roasting in front of the fire there is no atmosphere of steam round the joint at all; the air is free to play over its surface, and the cooking is done by radiated

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heat. We believe the process of open roasting is far superior to that of close roasting; the flavour of the meat so cooked is invariably better, and the tissue itself is generally more tender when it is cooked by roasting, and, consequently, more digestible. We are inclined to put forward the view that the cooking of meat by gas is less satisfactory than cooking by the open roast method, because in the former case the joint is cooked partly by ascending heat currents and partly by steam. According to this view, cooking by gas may be regarded as a hybrid process, that is to say, part boiling or steaming and part roasting. The constant stream of steam over the surface of a joint of meat is calculated to extract some of its flavour and to exert a toughening effect on the tissues of the meat. We do not think, however, that any difference between the effects of gas cooking and cooking by roasting or in the range oven can be regarded in a serious light from a point of view of dietetics. The differences, in our opinion, are due entirely to the different physical conditions under which the meat is cooked, and we may safely exonerate, we think, the gas cooker from any suspicion of poisoning the meat by reason of the escape of unconsumed gaseous products from the gas flame. The process of grilling meat exposes that food to a torrent of incomplete products of combustion compared with what happens in the gas cooker, and yet a grilled chop is very popular, 'the taste of the grill' (the sulphurous acid and, perhaps, a little smoke) being held in esteem; but the gases round the chop in this case do not contain anything like the proportion of hot aqueous vapour which is present in the gas cooker."—*The Lancet*, Feb. 2, 1907.

But in point of fact, nowadays everybody eats food cooked by gas, if not at home, then certainly in public places. Sometimes gas stoves give off an offensive odour, but that is not the fault of the fuel, but of the cook. Cleanliness of

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the apparatus and the utensils is imperative with gas stoves, because they are rarely set in chimney places; and that is a good thing. Such stoves only smell offensively when dirty, or when gas is being wasted by the flames under the boiling vessels being turned up too high.

The gas cookers now made for general household use, in various sizes, are designed for "all work." That is to say, the specialized appliances employed in separate pieces by caterers are here combined in one apparatus, which occupies remarkably little floor room for its culinary capacity. The type of English gas cooking stove, as illustrated (Figs. 68 and 68A), is meant to satisfy all the usual requirements of English family cookery. Therefore, its accommodations begin with a capacious roasting chamber, or oven, for the family "joint." It will be noticed on comparing a gas cooker with a coal kitchener, that in the former the oven is much larger, in the vertical sense, than in the latter. The reason for this peculiar shape of the gas oven is, that the utmost use may be made of the heat, which is applied at the bottom by means of gas burners in lines on each side. The heat from these burners rises through the oven chamber, which can either be left clear from top to bottom for the reception of a large joint of meat, or a turkey; or it can be temporarily divided,

Fig. 68.—Standard pattern Gas Cooker.

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at any height, into two sections by the insertion of a sheet iron "browning" shelf provided for the purpose. Really, the gas stove provides the user with *two* ovens, one over the other, of sizes as required for the viands to be cooked; and the same heat does for all. Suppose, for example, that the dinner to be cooked consists of a joint and a milk pudding, with vegetables. The oven is first divided horizontally by inserting the sheet-iron shelf at a suitable height to take the pudding in the top part of the oven. Then the gas at the bottom is lighted, care being taken to see that the large dripping pan which forms the removable bottom of the oven is in its place.

FIG. 68A.—Model Gas Cooker.

Experience has proved that the best way of applying the gas for roasting or baking is *inside* the oven, at the bottom. Several important advantages are hereby secured. In the first place, a free current of air must be admitted to the oven interior to enable the gas to burn. This means that the food is cooked in a current of air—that is, roasted, not pent up in a close hot box. Secondly, applying the heat directly to the victual in this way enables the roasting chamber to be jacketed outside with slag wool, for the retention

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of the heat; which makes for economy of gas. Thirdly, as the fire never touches the sides of the chamber, these can be enamelled, in the interests of cleanliness; thereby allowing for the inside of the oven being regularly washed out with soda and hot water—which is impracticable with a coal-heated oven.

The lower part of the chamber is the "roaster," as it is here that the gas burns and the fresh air flows in. The joint is therefore placed upon a grid-shelf at the lowest level, or hung by means of a hook from an upper grid-shelf. This is a detail which matters not, so that the meat is low down in the oven. It drips into the large dripping pan, which (without water) is in place to receive the fat in comparative coolness, being beneath the gas flames. Thus, the dripping never gets overheated, nor burns.

Above the roasting place, as already described, the sheet-iron shelf forms the division between this space and the oven proper. The sheet-iron gets hot, affording a top heat beneath and a bottom heat above it. Here is a comparatively cool space where puddings can soak. With experience, a skilful cook can pack a succession of things in this part of the apparatus, to cook in turn while the joint is doing below. Thus, with once heating, the oven can be made to cook two or three days' provisions.

In heating the gas oven, the gas must be turned full on, with the oven door shut, for twelve or fifteen minutes before the food is put in, when the gas must be lowered by one-half. Then, in the case of a large joint, the stove can be left to itself for the remainder of the time necessary for the cooking, at the rate of twelve minutes to the pound weight of meat. It is this certainty of action which largely accounts for the favour in which gas stoves are held by the women who have to do the work of a house, who are thereby released from bondage to the kitchen fire.

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The top of the gas cooking stove is finished off with a stout grid, beneath which are the boiling burners of different sizes. Makers have a variety of opinions respecting the disposition of these burners, and in selecting a family cooker it is expedient to choose one which has the boiling

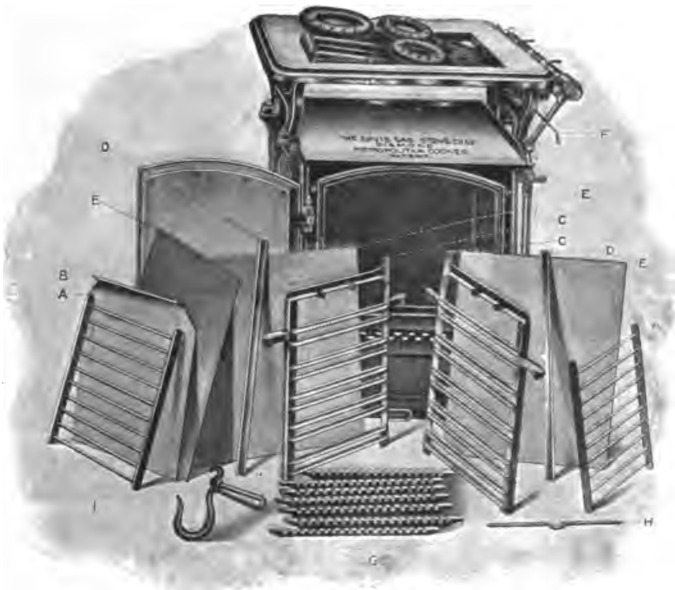

FIG. 69.—Parts of Cooker, removable for cleaning or repairs. A, grid iron shelves; B, "browning" shelf; C, side supports for oven shelves; D, locking bars; E, enamelled plates lining oven; G, top grid parts; H, I, meat hook and carrier.

rings intelligently distributed over the top, so as not to interfere with one another nor waste space. As a rule, these burners are too large for their real uses. A couple of small "simmering" burners should be provided on every stove above the smaller sizes, as these are the most useful burners of all. The temptation always is to burn more gas

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than is necessary. The quietness of gas flames is apt to mislead as to their power. Most cooks have to burn a few saucepans to learn this lesson. The gas flames should never show beyond the bottom of the pot.

Between the boiling top and the top of the oven is a space which accommodates dishes and plates for warming, and also the "griller." This is an arrangement of a grid and dripping pan to go underneath a burner with a radiating plate over it, which gets red hot in a couple of minutes, and forms a most useful quick-cooking apparatus. By this means the toothsome method of preparing food by grilling or toasting, which had become unavailable since the coal kitchener superseded the old-fashioned open "range," has been restored to the family kitchen. It is no "silver grill," but the results are the same. There is no part of the gas stove in more frequent use than this; therefore an ample and efficient grill burner is one of the points to look out for in the choice of a stove. Fig. 69 shows the component parts of a gas cooker.

The quickness with which a breakfast, lunch, or supper can be prepared at a pinch by the aid of a gas stove, is one of its chief recommendations. The author was instrumental in bringing this feature of gas cookery into prominence at the International Gas Exhibition held at Earl's Court, London, in December, 1904. Open competitions in the carrying out of simple breakfast and luncheon menus were organised, with the result of showing that it is quite possible for a deft hand to prepare a breakfast of grilled rasher and poached egg, toast, and tea, coffee or cocoa, in less than ten minutes, and quite a smart little lunch in double the time. Nor did this remarkable speed entail any sacrifice of the quality of the cooking; quite the opposite. It was not the cookery that was hurried, but the time of getting up heat that was saved.

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As an illustration of the capabilities of a gas cooking apparatus of the full family size, which can be hired of any gas company for about 3*s.* per quarter, an expert hand can easily prepare within an hour the following dishes at the cost of about 35 cubic feet of gas: Soup (from essence or tablets); baked or fried fish; cutlets; roast fowl or game; 5 lbs. to 6 lbs. joint; baked and boiled (or mashed) potatoes; green vegetables; legume course; boiled pudding; baked tart; savoury; sauces and gravy.

It is not necessary to connect the gas cooker oven with a chimney flue, nor to cover the apparatus in with a hood or canopy connected with a chimney; unless an exceptional amount of fish frying, etc., is required. The consumption of gas in the oven is never more than that of two or three flat-flame lighting burners, and with the stove in full operation is only about 30 to 35 cubic feet per hour, which makes little difference in the temperature of an ordinary well-ventilated kitchen or scullery. Indeed, the circulation of air round the gas cooker is commonly excessive, as the apparatus is usually relegated to a scullery, between two doors. This is not a good place for it; first, because it cannot be expected to work properly in a through draught, which blows the gas flames about, chills the oven, and often extinguishes the flames altogether when turned low; and, secondly, because it will probably not be kept so clean when put away out of sight. The best situation for the gas stove is in the kitchen alongside the coal range (or in place of it), well out from the wall, and in a good light. If kept in a proper state of cleanliness, and clean utensils only used on the boiling top (these should be kept specially for the purpose, not shared with [illegible] fire) and the boiling gas flames not allowed [illegible]nd the sides of the pots, no odour other th[illegible]ooking itself, will ever

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proceed from the gas stove, nor will the gas consumption be extravagant.

It is occasionally found that domestics untrained in the careful use of gas for cooking—as is now practised at many elementary schools—waste it by not instantly turning off the taps when done with. In the busy work of catering, or cooking for a number, this attention to the taps is hardly to be expected; and in such cases it is worth while to have the apparatus fitted with an automatic valve which reduces the gas to a glimmer when the weight of the pot is lifted from the top. This arrangement hardly meets the case of private use, where waste is due to carelessness or thoughtlessness. In such circumstances, if the cost of gas is found to be excessive, a slot meter can be had for the stove alone, and the servant allowed a reasonable sum to be put in it—savings being a perquisite. Gas cooking under these conditions is cheap.

It should be perfectly understood by the housewife that the family gas stove is capable of every kind of cookery, including the baking of bread, small fancy cakes—anything and everything in short, that the skill of the cook and the requirements of the household may demand of it. Any shortcoming is not the fault of the apparatus, when properly fixed and in good order, with an ample supply of gas. The last is essential, and any insufficiency of pressure should be reported to the gas office. If the user should not understand the use of the stove, application for help and instruction at the gas office will generally prove successful in eliciting the requisite information. Many thoroughly reliable cookery books, specially written for the gas stove, are extant, and can always be obtained of the stove makers. In order to prevent anything about the stove getting out of order (as well as to have a check upon its due cleaning by servants), it is desirable to let

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the gas company keep it in repair, if this service can be obtained.

The ordinary type of family gas cooker, with jacketed oven, internal flames, bunsen burners throughout, and all fittings dismountable, is the product of much practical experience of what answers best in the ordinary conditions of English housekeeping. The types of apparatus for the same purpose differ in other countries, in agreement with the different national styles of cooking. Thus, in France and Germany the pieces of meat are usually cut smaller, and the roasting part of the stove is consequently a less important feature of it. This cooking operation is frequently done in a chamber with top heat, like an enclosed griller. The whole apparatus is differently shaped from the English.

Luminous flame cooking stoves are made, but the liability of the burners to get out of order and deposit soot upon the vessels heated is against them. In strict fact, luminous and bunsen burners give the same quantity of heat for the gas consumed, but the former are less manageable, and cannot be forced beyond a limited power. The bunsen burner can be made of almost any desired power and shape, and as the bunsen flame is smaller than the luminous for the same gas consumption, it can be brought into closer contact with its work. Although it does not deposit soot when in contact with a cold surface, such as the bottom of a kettle of cold water, the flame suffers a partial extinguishment thereby, which results in the escape of acrid-smelling products of imperfect combustion. This can be avoided by so adjusting the burner tap that the flame *only just touches* the bottom of the cold vessel, when the process of combustion will not be interfered with, nor any odour given off. Waste of gas and a bad smell are not effects of burning much or little gas, but simply and solely of treating it carelessly and improperly. Besides, in all

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cooking operations by boiling, one of the troubles to beware of is the burning of the contents of the saucepan or stew-pan. This misfortune is always the consequence of having the gas too high under the pot (see p. 183).

Most of the annoyances and disappointments of gas cooking are due to burning too much, rather than too little, gas. The instructions of the cookery books as to heating up the oven first by a liberal use of gas *before* anything is put in it, and the careful turning down of the oven burner as the cooking proceeds and nears completion, give the chief secret of success.

The proper temperature for the inside of an oven, *before* commencing to cook, differs according to the nature of the purpose intended. It is lowest for small cakes, and highest for bread-baking or the roasting of thick joints of pork. Some gas kitcheners of household patterns are fitted with an oven flue damper, which when thrown fully open is supposed to constitute the interior a "roasting chamber," and when as near closed as it will go, converts the same hot space into an "oven" for baking. Many modern makes of these stoves have no such fitting, which, in fact, is unnecessary. There is no tangible difference between the operations of roasting and baking in an internally-heated chamber, for the reason that such a chamber can never be quite closed, or the gas flames would be extinguished. A free current of fresh air through the cooking chamber is desirable, and, as the example of grilling and toasting proves, does not affect the action of cooking. By far the greater part of the work of a gas oven is done by radiation from the hot sides and crown, not by the convected heat from the gas flames, which is why the gas must always be lighted up and turned full on in the oven for a considerable time—twelve minutes to a quarter of an hour—before any cooking is attempted.

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Therefore, the notion of a damper being required for a gas oven is unfounded, and where this attachment is provided it can be let alone. Either with or without a damper on the flue, the initial temperature of the oven must be raised to about 400° F. for small, light cakes, and to 500° F. for bread-baking or pork-roasting. In all cases, *without exception*, the gas must be lowered when the articles to be cooked are put into the oven. In the case of small goods, the gas is again lowered every five minutes, and turned off altogether five or ten minutes before the allotted period for the cooking has elapsed. Bread-baking makes the heaviest demands upon the power of an oven, by reason of the large volume of steam given off by the dough. It can be done quite well in a gas oven, but nothing else can be cooked in the oven at the same time. Some years ago a serious attempt was made to heat bakers' ovens by gas, but the result was not satisfactory, the consumption of gas being too great in ovens as ordinarily constructed. On the other hand, special gas ovens for confectionery are quite successful, having the particular recommendation that the heat can be perfectly regulated. By this means the effect of steam heat can be obtained for a small outlay as compared with the cost of a regular steam baking plant.

When gas ovens are required for drying purposes, in certain trades, external heating is necessary, and the ovens must be made to order, according to the use to which they are to be put and the degree of heat desired.

For many purposes it is required that the temperature of hot-chambers, drying rooms, etc., should be maintained above a certain minimum. This condition is easily fulfilled by gas heating, with the aid of a thermostatic valve on the gas supply. Different patterns of these appliances are made, but they all rely for their operation on the expansion of a metal or a fluid with increase of temperature. A

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brass rod, for example, or a quantity of mercury in a tube, can be depended upon to increase in length when heated, and it is obviously easy to make this movement progressively close a gas valve and so check the source of heat. In this way the minimum temperature of a room can be kept throughout the year from falling below a predetermined figure, say, 60° F.

Amongst the minor, yet extremely handy and convenient applications of gas to purposes of a culinary character, must be mentioned for special commendation the roasting of coffee. Simple and effective appliances for this operation are in the market, which will enable the connoisseur of coffee to please himself with the beverage in its highest perfection. Coffee roasting machines are made in all sizes, from the household size, capable of roasting ½ lb. of berries, (and, of course, equally serviceable for roasting the quantity required for a single cup, which is done in six minutes) to those required by grocers, taking any quantity up to 28 lbs. at a time. The cost for gas is negligible, the roasting of 1 cwt. of berries not burning more than 3*d.* worth of gas. Thus, there is no reason why those who prefer their coffee freshly roasted and ground should not have their taste gratified, as the whole operation need not take ten minutes from green berry to cup.

Carving tables, hot closets for plates and dishes, hot-plates, steaming closets, grilling, roasting, and boiling [illegible] are amongst the specialised forms of gas cooking [illegible] used by caterers and in large [illegible] kitchens. One well-known firm [illegible] a year for cooking gas. [illegible] gas cooking on the business side [illegible] demands can be [illegible] and served [illegible] can be laid on

temporarily to a neighbouring main. Restaurant roasters are made as large as 7 feet by 3 feet 8 inches by 2 feet 10 inches, with an oven capacity of 66 inches by 40 inches by 30 inches. Such an oven is capable of cooking 500 lbs. of meat at a time. It would be enamelled throughout inside, with loose hanging side runners and self-supporting grid-shelves, thus providing every facility for the thorough cleansing so desirable in cooking on every scale, but not easy to secure unless rendered quite unlaborious. For this reason a high and ornamental degree of finish inside and out is desirable for cooking apparatus, to encourage those who use them to keep them in the best order. Gas steam chests are fitted with safety locking attachments to prevent opening while the steam is on.


FIG. 70.—Gas "copper."

Temporary or permanent boilers for clothes, washing-up, etc., are conveniently heated by gas, which enables them to be placed anywhere, without reference to a chimney (Fig. 70). The following statement of the actual cost of boiling water by gas is on the authority of Mr. W. J. Atkinson Butterfield, analytical chemist, who says: "I have ascertained by trials the exact consumption of London gas by a common boiling burner, costing one shilling, when a quart of water is raised from 62° F. to 212° F. in (1) a much befurred iron kettle capable of holding over two quarts, and (2) a clean aluminium kettle of one quart capacity. The first case represents bad, and the second tolerably good, but not ideal, domestic conditions of the use of gas for boiling. The consumption of gas and its prevailing price (2*s.* 11*d.* per 1,000 cubic feet) in the city and west end of London

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were:—1·72 and 1·51 cubic feet, and 0·060*d*. and 0·053*d*. respectively, for the two sets of conditions named. . . . About 40 per cent. of the heating power of the gas was utilised." Many experiments by the author confirm these results, which prove, broadly, that the cost of gas for boiling a quart of water may be taken as about one-twentieth of a penny. By fixed water heaters, circulating or other, a considerably higher proportion of the heat of the burnt gas is utilised. It is a noteworthy circumstance in connection with the heating of water, that cleanliness of the outside of the vessel is of more importance for saving fuel than the furring of the inside due to the hardness of the water. A very little sooting on the bottom of a kettle or boiler makes a great difference in the rate of heating the water, and consequently in the gas consumption.

Several ingenious arrangements have been made for economising the heat disengaged from a domestic cooking stove, by warming water. It is evident that the benefit of such devices depends upon the duration of the culinary operations, and, therefore, that they are not of much use where there is not pretty constant cooking. In particular cases there is economy in a good combination of the kind, as the hot water for washing-up can be had without burning any extra gas. Gas cookers are also made with fires attached for warming the kitchen, airing clothes, heating the bath water, etc. They are for householders who pin their faith to gas for kitchen use to the exclusion of coal; and they require to be fitted into the kitchen fireplace in the place of the coal range. The recess should be tiled at the back and on the sides, and the compact apparatus then has a particularly neat and clean appearance. Clearly, it abolishes the whole of the labour of bringing coals, keeping up the fire, removing ashes, and black-leading, for which is substituted merely the weekly cleaning up of the stove.

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Therefore, the saving of this labour should be taken into account against the cost of gas, which would run to about a penny or penny-farthing an hour when full on.

Quite at the opposite end of the scale of culinary appointments are the portable gas cookers, which are low priced, and answer very well for the summer requirements of small families, as they stand on top of the disused coal range. This is a consideration where space is limited. These stoves are economical of gas, the boiling being done on the top by the waste heat from the oven, and the heat is furnished by two or three luminous flame burners. No fitting is required; but, as with all temporary gas connections, flexible metallic tubing should be used, not rubber, which is perishable. The latter kind of gas tube may be safe when new, but there is no knowing how long this quality may continue, and rubber perishes with age, whether used for gas tubing or for any other purpose.

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CHAPTER IX.

THE HEALTHFULNESS AND SAFETY OF GAS IN ALL ITS USES.

Effects of burning gas in living rooms—Composition of pure and polluted air—Temperature effects—Curing of draughts in churches and public halls—Sulphur in the atmosphere—Pernicious character of town fogs—The question of house-cleaning—Dirty ceilings and stuffy rooms—Curing the smoke nuisance of towns—The fire risks of gas—Gas escapes and explosions—Practical hints and cautions.

QUESTIONS concerning the salubrity and safety of town gas in respect to any of its uses refer either to what may happen subsequently to its regular and proper combustion, or to the effects of its irregular and catastrophic inhalation or ignition. The former are perhaps the more frequent, and they generally arise in connection with the comparison of gas, to its disadvantage, with some other illuminant. Being a light of combustion, and therefore requiring to be supported by the oxygen of the atmosphere, in return for which it yields carbon dioxide (CO_2), gas is sometimes condemned out of hand by amateurs of hygiene, who, with little knowledge of the subject, jump at once to the conclusion that an illuminant which takes the vitalising oxygen from the air and returns the inert gas carbonic acid, must be noxious. This is far from being the opinion of persons [illegible]

per cent. by volume—which does not sensibly vary in different places.

Indeed, the wisest expositors of hygienic principles regret the prominence that is ignorantly given in popular writings to this particular matter, because it distorts the view of the subject as a whole, and leads to wrong conclusions. Thus in "Helps to Health," Mr. Henry C. Burdett remarks that "nine hundred and ninety-nine people out of a thousand believe that the ordinary impurities of air in inhabited rooms are due to carbonic acid gas, and that to provide against this impurity is to secure an adequate and healthful supply of air. As Dr. Billings has humorously declared, the average ventilating enthusiast holds this as the dogma of true ventilation. In his papers on the subject he will enlarge on the deadly nature of this subtle poison . . . . Carbonic acid gas in the proportion in which it is met with in the worst ventilated rooms is not in itself a dangerous or even an injurious impurity."

Dr. Samuel Rideal, Fellow of the Royal Sanitary Institute, has stated that "pure carbonic acid contents of 0·6 per cent.—*i.e.*, more than tenfold the usual—are not poisonous; and it is only when 3 per cent. is reached that respiration becomes slightly deeper and more frequent." Dr. Whitelegge also, the adviser on sanitary matters of the Home Office, testifies in the same sense. A Departmental Committee on the Ventilation of Factories and Workshops has admitted the reasonableness of a higher limit of carbonic acid for gas-lit factories than for similar interiors otherwise illuminated, it being pointed out that a moderate increase of the carbonic acid and diminution of oxygen content of the air is not in itself prejudicial to health. As a matter of fact, the sense in which sanitary science now regards the carbonic acid content of the atmosphere, is that of an index of

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the probable presence of positive poisons and impurities resulting from overcrowding. Thus, the Home Office inspectors are constantly sampling the air of schools, factories, and workrooms, which is tested for CO_2 merely as a guide to the state of the ventilation. It is not the presence of a little more CO_2 that matters, but the company it keeps when it is the product of respiration.

The proportion of carbonic acid in the air of occupied rooms is measurable with ease, and it is the only change in the air attributable to the occupation of a room which can be determined in a trustworthy manner. Consequently, certain standards of what is permissible in carbonic acid content have been stated in textbooks of hygiene, but it must be understood that these standards refer to carbonic acid which is clearly of respiratory origin. Nobody could dream of applying them, say, to the case of a soda-water bottling shed, where work is constantly carried on in an atmosphere which may show 0·2 per cent. of CO_2, or more. In the case of schools or workrooms, associated with the carbonic acid are all the other products of human respiration and skin exhalation, including uncondensed water vapour, bacteria, traces of organic matter, and the undefined "spirotoxines," which have hitherto been regarded as the real offenders in determining the unpleasantness of a badly ventilated room. Pure CO_2, the product of the combustion of a carbonaceous fuel in air, or of a chemical reaction, is quite inodorous and in no sense a poison. It is merely an inert gaseous substance which is capable of occupying the place of air, but is easily scattered by ordinary ventilation. It is very remarkable that the moment carbonic acid gas mixes with the air outdoors it sinks to its appointed level in the natural order of the composition of the atmosphere, so that there is no appreciable difference between the proportion of this constituent of the

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air in a breezy city street, or on a hillside far removed from the busy haunts of men.

The pure carbonic acid which results from the combustion of town gas is produced in about the proportion of one-half by volume of the gas burnt. Thus, every 5 cubic feet of gas, however burnt—whether with the luminous flame, or the atmospheric flame with or without a mantle—produces about $2\frac{1}{2}$ cubic feet of carbonic acid. The other products of combustion will be $6\frac{1}{2}$ cubic feet of aqueous vapour, and about two grains of sulphur oxidised to sulphurous or sulphuric acid (S. Rideal). The water is considerably the largest product. It is never sufficient, however, to saturate the air of a room in which it occurs as an effect of the gas consumed for lighting. Consequently it does not all condense on the walls, on the ceiling, or on solid articles in the room, under normal conditions. Usually, when modern gaslights are in use, the air of the room is also at a comfortable temperature for the inmates—say, about 60° throughout the evening. Such air holds a large quantity of water in suspension, and the amount is constantly and rapidly changing. The mean humidity of the air in the British Isles is stated by Mr. Clifford C. Paterson, of the National Physical Laboratory, to be ten litres of water vapour per cubic metre of dry air—5·4 per cent. by weight, and 1 per cent. by volume.

Referring to the example of the small dining-room discussed on p. 128, it was shown that the quantity of gas required to satisfactorily light an apartment of 2,000 cubic feet capacity is not more than 4 cubic feet per hour. Evidently the effect of adding to the air of the room the whole of the water vapour, about 5 cubic feet, produced by the burning of this quantity of gas, is negligible. So minute an amount cannot make the smallest noticeable difference either way. It would not matter even if the

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atmosphere of the room were stagnant, and there was no ventilation. Inasmuch as in fact the air of all inhabited rooms of ordinary construction, with wooden floors, and plaster and brick walls and ceiling, and a fireplace, changes from once to three times or more in the hour, even an excess of aqueous vapour would have little chance of being condensed inside. An important consideration growing out of the foregoing statement is, that as the sulphur acids produced by the burning gas are very soluble in water they must go with the water vapour wherever it goes.

What is true of the water vapour produced by burning gas in the quantity required for lighting, is also true of the carbonic acid which is similarly produced in far smaller quantity. The extent of the "air pollution," as amateur sanitarians sometimes call it, by carbonic acid thus originated is, in the case now under discussion, 2 cubic feet per hour. If the air of the apartment is assumed to be changed twice an hour, which it cannot be prevented from doing even if no door or window were opened, the proportion of added carbonic acid in the air at any moment would amount to only 0·0033 per cent. In point of fact it is not measurable. There are no other gaseous products of the combustion of gas to be accounted for. There remains only the sensible heat resulting from the burning of gas for lighting, which of course might be objectionable if in excess, or where a very large quantity of gas is burnt for this purpose without sufficient ventilation.

In the example of the small room, careful tests made during long winter evenings with one inverted gas lamp and a coal fire burning, a window being opened six inches at top, and one or two persons present, never indicated greater differences of temperature than the following:—Thermometer laid on carpet, 57°; on wall, 4 feet from floor, 59°; at ceiling, 61°. It can therefore be reasonably concluded that

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the elevation of air temperature due to the gaslight is not sufficient to constitute an objection to its use.

In the case of churches and public halls full of people, the small but positive warming of the upper portion of the atmosphere by the gas used for lighting by incandescent burners, performs a valuable service in keeping the gaseous emanations of the crowded assemblage aloft, and preventing them from becoming chilled by contact with a cold ceiling or open roof, and thereby pouring down again upon the heads of the people in a particularly noxious form of "draught." The latter uncomfortable and unwholesome effect is only too commonly experienced in churches and interiors of a similar order, in which the warming is done by hot water or steam pipes at the floor level, and there is no ceiling. The carbonic acid and water vapour, with all the other exhalations of the crowd of persons present, being warm and light, first rise into the upper stratum of the atmosphere,

Note.—To find the dew point, or temperature at which air will begin to deposit moisture, Glaisher recommends observation of a wet and dry bulb thermometer. The difference between the readings is to be multiplied by a constant which varies with the dry bulb temperature as follows, and the product subtracted from the dry bulb reading—

40° to 45°	factor 2·2
45° ,, 50°	,, 2·1
50° ,, 55°	,, 2·0
55° ,, 60°	,, 1·9
60° ,, 65°	,, 1·8
65° ,, 70°	,, 1·8
70° ,, 75°	,, 1·7
75° ,, 80°	,, 1·7
80° ,, 85°	,, 1·6

Example.—If the atmosphere of an apartment indicates a temperature of 75° by the dry bulb, while the wet bulb indication is 5° lower, then $5 \times 1{\cdot}7 = 8{\cdot}5$, and $75 - 8{\cdot}5 = 66{\cdot}5°$, the required dew point. If walls or windows are at a lower temperature than this their interior surfaces will be covered with condensed moisture.

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cooling down as they go, until they finally lose their ascensional power by becoming chilled to the temperature of the underside of the roof, and of the outer walls. If there should be a range of clerestory windows, the chilling of the atmosphere at this level is thereby accelerated. The water vapour condenses upon the glass and the walls as a foul steam, some actually running down as dirty water. Later, this moisture will evaporate again, giving off that sickening odour with which those who are in the habit of attending the early Monday morning services in a fashionable church are only too familiar. Meanwhile, the chilled carbonic acid and already breathed air are falling heavily down upon the people, who shiver and pull up their collars and wraps, peeping indignantly round for the open doors or windows to which they erroneously attribute their sufferings. Unfortunately, it is no fresh if rather too keen air from outside which they feel, but a vitality-lowering mixture that every minute grows more and more unfit to breathe. The only practicable remedy for this state of things is to apply some heat to the atmosphere near the roof, so as to keep the foul air up out of the possibility of doing harm until the usual outlet shafts or fans, or other ejector arrangements if any, can get hold of and expel it from the building. This can be done either by fixing steam or hot-water piping against the walls at the high level, or, incidentally to the lighting, by the warmth of the gas. In the latter case it will sometimes be necessary to light up the gas in the daytime.

An exhaustive series of experiments, directed to ascertain what effect, if any, is produced on the atmosphere of inhabited rooms lighted by gas, having special regard to the sulphur present in such gas and burning, as already stated, to sulphurous and sulphuric acid, was conducted in the South of London in 1904 by Drs. Otto Hehner and S. Rideal. The first care of the analysts was to determine

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the average amount of sulphur impurities existing in the air of the town, which they found to vary between about one-quarter of a volume in a million in summer, and slightly less than one volume in a million in winter. In exceptional circumstances the proportion may rise to five volumes per million, when the presence of sulphur can just be detected by the senses. This confirms the general impression of what can be smelt and tasted in the atmosphere during very bad black fogs.

The question of how much sulphur may occur in the air of a gas-lighted room can be easily answered by referring to the quantity disengaged by the gas actually burnt, as already briefly stated on p. 217. Going farther into this subject, in the light of Hehner and Rideal's report, it is a matter of easy calculation to show "that only when the air of a room is so vitiated that the carbonic acid has reached 50 volumes per 10,000 can the sulphur contents exceed the limits of perception; and these correspond to the maximum impurity as regards sulphur of outside air in foggy weather." It is evident from these theoretical considerations that the sulphur content of gas cannot be of any significance in a room which would not be condemned from other considerations. In point of fact, however, when the matter was put to the test of actual experiment, it was found that the sulphur content of the air of rooms lighted by gas "is invariably very much smaller than the calculated amount." It was proved by a long series of experiments, conducted by the two analysts independently, that the sulphur acids in the air of such rooms, when of ordinary construction, with large quantities of lime in the walls and ceilings, are energetically absorbed and neutralised by the lime. It resulted from this action of the lime that the amount of sulphur found when burning different kinds and quantities of gas in an ordinary small room, was from one-sixth to

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one-twentieth of the quantity actually introduced. In no case did the investigators find the amount of sulphur impurity in the air larger than one-fourth of the quantity which has been recognised by the Manchester Fogs Committee as productive of irritation of the nose and throat, and in that solitary instance the gas contained 46 grains of sulphur in 100 cubic feet, and the air of the room 45 volumes in 10,000 of carbonic acid—a quite impossible quantity for occupied apartments.

Under the ordinary conditions of town life, therefore, not only is there no increase in the sulphur content of a room in which gas is burnt for lighting, over that in the outside air; but there is even a decrease, owing to the rapid purification by the walls and ceiling, which goes on even when no gas is burnt in the room. Observations on the tarnishing of bright metals also show that this effect is chiefly due to the condition of the outside air. One day's fog will produce more tarnishing than any number of evenings' gas lighting. This is true in the knowledge of every housewife and hardware shopkeeper. The harmful effects of this atmospheric sulphur impurity, which is chiefly due to the burning of coal, are increased by the soot and tarry matters with which it is associated in fogs. "Samples of soot in London contained 4·6, in Manchester 4·3, and in Glasgow 7·9 per cent. of SO_3, equal to 1·84, 1·72, and 3·16 per cent. of sulphur respectively. From experiments at Leeds and Manchester it was estimated that the soot which fell in twenty-four hours per square mile was in the former case 250 lbs., and in the latter about double that quantity during fog. The dust from twenty square yards of glass roofs at Kew and Chelsea contained nearly 5 per cent. of SO_3, equal to 2 per cent. of sulphur. A concentration also occurs from rain and snow."

As to the amount of sulphur sent into the atmosphere as

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acid gases every day in London by the three chief combustibles, Dr. Rideal calculated it for 1904 from the Board of Trade returns of the average quantities used to be approximately as follows :—From coal, daily, 981,792 lbs.; from gas, 893 lbs.; from mineral oils, 743 lbs. The sulphur arising from the burning of coal is, therefore, 1,100 times that attributable to gas, while the petroleum and naphtha is very nearly as sulphurous as gas. On the subject of the tarnishing of bright metals Dr. Rideal testifies by experiments in 1903 with silver-foil, tin-plate, picture-wire, curtain-chains, white metal, and electro-plated spoons, that such articles were affected far more rapidly and deeply by the outside London atmosphere than by the air of rooms in which gas is burnt. (See, for fuller details concerning this and the allied questions arising from the phenomena of town fogs, the Official Report of the Conference on Smoke Abatement, arranged by the Royal Sanitary Institute in conjunction with the Coal Smoke Abatement Society, held in December, 1905.)

The conclusion of this aspect of gas lighting is expressed by Dr. Rideal as follows :—"Burning coal gas in a room does not increase the sulphur content of the air at any time to that reached in foggy weather in the outside air, because the water produced in the burning of gas is far more than sufficient to absorb the sulphur oxides, and this water condenses them on to the ceilings and other basic materials present, where they become permanently fixed. A good whitewashed ceiling can thus act as an acid scrubber for many years." This operation of a limewashed ceiling can be observed anywhere in a town house, after it has been done some time, by the filtering action it exerts on the dust and soot-laden atmosphere. In the course of a year or more (depending on the relative dirtiness of the atmosphere of the locality) the lathing and joists of a ceiling can be

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distinguished by the comparative lightness of colour of the whitewashing where they run. Between the laths the ceiling is darkened by the greater quantity of dirt left behind by the air that has passed through the plaster in virtue of the physical action called "osmose." The plaster itself is porous, and the stratum of air immediately in contact with its under surface is usually warmer, and therefore lighter and thinner, than the air on the other side in the space between the joists. Consequently, whenever this difference of temperature exists on the two sides of a wall or ceiling there is a more or less rapid transference of the air from the warmer to the cooler side, leaving its dirt on the surface of the medium. Therefore the degree of blackening which appears upon a dirty ceiling, and in a less degree upon the wall-papering (which is also porous), is governed much more by the average condition as regards suspended dirt of the outside air, than of anything that arises inside the house, except smoky chimneys.

This kind of dirtying of a house, which to some extent injures the furniture also, is very little affected by the consideration whether gas is burnt for lighting or not. Commonly, in partisan literature, the expense of periodical house cleaning is charged against gas lighting as though it might be dispensed with in the absence of gas. This is a delusion which no true sanitarian would encourage for a moment. To put the matter crudely, but still upon its true basis, human habitations stand as much in need of periodical cleaning as do cattle-pens of whitewashing. No place of human occupation ought to be so elaborately and expensively decorated and upholstered that the occupiers cannot afford to have it thoroughly cleaned out and done up afresh at reasonably frequent intervals. The wise counsel in regard to dress—"Never wear anything so costly that you cannot afford to spoil it and buy more," applies with

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equal force to that larger habiliment which is called our house.

If the surrounding atmosphere is dirt-laden no house can long remain clean. The examination hall of the medical profession on the Victoria Embankment, London, was decorated in pale tints, and steam radiators installed to warm it. Result: a stain of sooty matter on the walls above every nest of steam piping. To say nothing about oil lamps and paraffin candles, which are essentially dirty luminants, any kind of illuminating or warming appliance will blacken walls and ceilings in its vicinity if the atmosphere is dirty. On the other hand, in the country an old-fashioned flat-flame gas burner may be in use for years close to a whitened ceiling and cause no stain. It is not any smokiness of the gas burner which makes ceilings dirty. Gas burners, in point of fact, do not smoke. But when there is dust in the atmosphere this gets entrained in the current of moist, hot air that rises from a burning body, like a gas flame, and its charred embers become stuck against the plaster through which much of the heated air itself has passed. Measures can be taken to distribute this action as much as possible by placing deflectors over the gas flames. Incandescent gas lamps do not blacken ceilings so much as flat-flame burners, not because they are intrinsically cleaner, but simply because they do not yield so much heated combustion product. Incandescent electric lamps partake of the same extenuating circumstance, but the effect ensues eventually all the same.

Really, from the hygienic point of view, the dirt of a house which is not seen is worse than that which is seen. For the dirt which cries for removal from ceilings and walls and hangings is little more than grit and soot. Comparatively harmless, both. But the foulness [illegible] lurks in rooms constantly occupied by day or night [illegible] der

T.G.

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kind. It may not always be visible, although it can often be smelt. It is that which necessitates the thorough repainting of the liner after her cruise; and calls for the wholesome domestic upheaval of "Spring" or Autumn "cleaning." They do an ill service to the community, who pretend that the adoption of any particular method of lighting or warming or decorating abrogates the necessity of cleaning the house. The same remark applies to the ventilation of public buildings, factories, warehouses, and workshops. The question whether such crowded interiors are lighted by a "light of combustion" or otherwise is immaterial to the issue of how the air shall be kept wholesome. This has been completely established by exhaustive tests carried out by Dr. Percy Frankland and others, which show conclusively that the respiratory requirements of the occupants of enclosed spaces as regards the supply of fresh air far exceed every other consideration in this regard. So much, indeed, is to be inferred from the physical facts that whereas a full-sized incandescent gas lamp does not need for its complete combustion more than about 21 cubic feet of air per hour, human beings are allowed "from 210 to 1,200 cubic feet per hour per head of inmates in ordinary good health. In public schools 1,800 cubic feet per head per hour is recommended; for theatres and concert-halls, from 1,500 to 3,000 cubic feet; for hospitals, from 4,000 to 6,000 cubic feet." And these allowances, it may be observed, are for every hour of the twenty-four for buildings constantly occupied.

With regard to the wholesomeness of gas cooking, the record speaks for itself. In respect to gas heating of living and sleeping rooms, medical testimony and practice has already been adduced. In addition, it should suffice to refer to the report of the Coal Smoke Abatement Society's tests of gas-warming stoves and gas fires, published

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in the *Lancet*, November 17th, 1906. After having exhaustively tested the performance of thirty-two different stoves, the report states that such an apparatus, assumed to be properly constructed and provided with a flue sufficiently large to carry away the products of combustion, "is quite as satisfactory (as a coal fire) from a hygienic point of view, and does not in any way vitiate the air of the room, nor does it produce any abnormal drying effect." Of flueless stoves it is stated that "with plenty of ventilation they would be very suitable for warming rooms or passages where no flue existed to which an ordinary gas fire might be connected." Dr. Rideal reports of the latter that where the ventilation is not sufficient the heat produced would call for the turning out of the gas long before the output of carbonic acid would become oppressive, not to speak of becoming dangerous to health.

Besides this assurance that in using gas for any ordinary purpose, the householder is incurring no risk of injury to the health of the inmates, there is the pleasing reflection that by the same means he is contributing to remove the nuisance of smoky skies which has for so long disfigured English towns. Gas is the sole practicable cure for this crying evil.

With regard to any dangerous effects which are to be guarded against in respect of gas explosions and fires caused by escapes of gas, it is vouched for by the Public Control Officer of the London County Council, that the modern extension of the use of gas by prepayment meters amongst those who may not improperly be classified as the more careless order of the metropolitan population, has not only been unattended by any increase of the statistics of fire "accidents," but has brought about a striking decrease of the number of such accidents due to petroleum lamps. The fire insura[illegible] of gas apparatus,

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provided iron piping or metallic flexible tubing is used for the connections. Indeed, stand-by gaslights are required for all theatres and underground passages of railway stations, etc., and are strongly recommended as a fire and burglary protection for staircases and corridors of hotels, schools, and other populous buildings and public institutions. The standing order in all such establishments recommended by Captain Shaw of the Metropolitan Fire Brigade, was, "Turn up the lights everywhere on the first alarm of Fire!" darkness being the chief factor in the creation of panic. For this and other reasons, it is a mistake to shut off the gas at the meter in houses occupied by night. In very large establishments the main cock may be closed and the pipes kept charged through a small by-pass; but in the case of ordinary dwelling houses the gas should never be shut off. To do so is not only to debar the use of pilot lights and prevent the burning of watch lights, but it creates a risk of explosions due to the accidental leaving on of lights in bedrooms and remote apartments. These, of course, are put out by the closing of the meter cock, but they are also inadvertently opened again unlit when the gas is turned on next morning. If nobody should happen to be in the apartments in question, the gas may go on escaping for hours unnoticed, until someone enters the room with a light. The greater number of private house gas explosions are caused in this way. It is safe to aver that only a very small percentage of gas explosions are due to anything but this mistaken practice, or to rank carelessness.

It seems to be too great a tax on human intelligence to insist that when a smell of gas is noticed, the source should never be sought with a naked light. Just as there are always fools who "didn't know it was loaded," so there are others who *will* strike a match to find out where an escape

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of gas comes from. Minor explosions and "bangs" when gas cookers and fires are lighted, usually indicate the careless use of matches. People who have to do with the lighting-up of gas apparatus should be brought into the habit of using a thick wax taper for this purpose. It is more convenient, safer, and cleaner than the promiscuous striking and dropping of matches. Careless servants occasionally turn on the gas at a stove or fire without having the light ready over the burner to ignite the gas immediately. The result is a "bang," and perhaps some singeing of hair and clothes. Nobody ought ever to be left to find out for him or herself how to light the gas, but should always be shown by someone who knows. Gas is perfectly harmless when properly treated, and its great point of safety lies in its inability to take fire by itself. It is not liable to mysterious or hidden ignition, but will only light from a flame or electric spark. It will not warm up gradually, like glowing embers, until it bursts into flame, and, therefore, it is never a cause of explosion or fire except by the provocation of a light, or by the carelessness of some human agent on the spot.

Should a smell of gas be noticed indoors, all doors and windows must be instantly thrown wide open and the premises vacated. If this happens by night, caution is required in arousing sleepers, lest a match should be inadvertently struck. It is better, therefore, in a bad case to open the windows and doors first. Usually it is easy to track the source of an escape of gas by "following one's nose," and a person familiar with the house will have no difficulty in feeling for every gas tap in the dark. In most cases the mischief will be discovered in a tap left on, or a flexible tube may be found pulled off. Children sometimes play with cooking-stove taps when nobody is looking. If there is an old-fashioned water-slide pendant in the house, it may drop

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and the gas pipe become unsealed. These antiquated fittings should not be kept in use at the present time, when there is no longer any need for their multiple arms. One incandescent burner, upright or inverted, will advantageously supplant a 3-light "chandelier," and a 2-light pendant will give more light than a 5-branch one of the old pattern with flat-flame burners. Attempts to adapt these antiquated fittings to the new method of lighting are never sightly, and there is no artistic merit in them to make them worth preserving. They have had their day, and should give place to the lighter, more graceful, and safer fittings specially made for incandescent burners, which are never on the water-slide principle.

Of late years there has been some increase of gas explosions in houses not referable to any cause inside the premises, which in some instances have not even had gas laid on. This is due to gas finding its way into the lower part of the house from a broken street main. The origin of this peculiarly objectionable form of misadventure is in the combination of heavy road traffic with impervious road coatings and pavements. Traction engines and their trains break the mains, sometimes of gas, sometimes of water; and the escaping gas may be kept down by the hard and continuous surfacing for a long way before it finds an opening into the air. Cases are on record of gas explosions occurring 80 yards away from the leak. The only means of preventing an explosion in such circumstances is to open up the house, and notify the gas company. The precaution of smelling for gas is to be specially recommended on entering premises that have been shut up unoccupied for any period. For this reason, it is prudent not to strike a light immediately on entering an empty house, or to go in while smoking. Tobacco will not of itself light gas, but it may mask a slight smell of it. If gas is smelt, and the house

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thrown open as advised, assuming the escape to be found and stopped, it is necessary to allow a sufficient time for the explosive mixture to clear out of the spaces between the ceilings and floors, and in the roof, before allowing a light. Some bad explosions have been due to neglect of the latter precaution after the house had been left empty for a "week-end" with a leak in it. Of course, if premises are to be so left, it will be a prudent act to shut off the gas at the meter and remove the handle of the main cock.

With regard to smelling gas—as with any other odoriferous matters—some people are keener-scented than others, but invariably the sense impression fades away after the first perception. Therefore, if a person has been in a gassy atmosphere for any length of time, as would be necessary in order to seek for the escape, open the doors and windows, etc., he may not be a trustworthy judge of the completeness of the ventilation process, and had better call in fresh assistance for this purpose. This dulness of the sense of smell accounts for the mistakes sometimes committed by gasfitters in leaving leaks in their work, which is inexcusable, of course, but not unnatural.

In the event of persons being found overcome by breathing gas, the first thing to do is to carry them right out into the open air—into the freshest air that can be reached—and there let them be laid on the back, the tongue drawn forward and artificial respiration applied vigorously until medical assistance arrives. If taken in time, the influence is easily dispelled without medical attendance, as the gas readily passes out of the lungs. It is only when the inhalation of gas has been going on for a considerable time that grave consequences are to be feared.

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CHAPTER X.

TOWN GAS FOR POWER GENERATION, INCLUDING PRIVATE ELECTRICITY SUPPLY.

Brief history of the gas engine—Beau de Rochas and the Otto "cycle" —Fundamental principles of the gas engine—Its practical advantages—Economy in power transmission—An example—The internal-combustion motor criticised—Compounding impossible—Importance of compression of the charge—The large gas engine—The fixing and working of engines using town gas—Gas-generated electricity for private consumers—General survey of the subject —The economics of electricity generation and supply.

The gas engine is one of the most conspicuous amongst all the triumphs achieved by mechanical engineering within the life of the present generation. It is classified scientifically as an "internal-combustion" motor, because the source of its movement and power is contained in itself, and is not derived from an outside origin like steam in the steam engine, or electricity in the electric motor. A long stride was covered in the direction of economising and increasing the handiness of power machinery when the gas engine, using town gas, was made a practically successful machine by Dr. Otto in 1876. The idea of an explosion motor was older than the steam engine, a cylinder-and-piston engine to work by gunpowder having been tried as early as 1678. A gas turbine (which has not yet been made a success) was patented as soon as coal gas was discovered, in 1791, and cylinder engines on correct principles were patented before 1801. It was not until 1860, however, that a fairly practical gas engine was put on the market

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by Lenoir, but it was a very extravagant consumer of gas, using about 100 cubic feet per horse-power, and had many mechanical shortcomings. Shortly after, a gas explosion engine was brought out by Otto and Langen, in which the piston was blown vertically upwards by the force of the detonation of an explosive mixture of gas and air in the cylinder. The piston flew up freely, but upon returning with the weight of the atmosphere upon it, the piston rod, being made in the form of a rack, engaged in a pinion and pulled it round. This was therefore really an atmospheric motor. The gas consumption was about 40 cubic feet per brake horse-power per hour, which brought the engine within the scope of industries using small powers; but the noise and vibration were great drawbacks to its use in town factories.

Up to this date, 1863, no working gas engine had been made upon the principles embodied in those now in operation; but it is remarkable that at this period these principles were actually set out in a French patent specification of Beau de Rochas. This French engineer laid down four conditions as necessary to be observed for the perfect utilisation of the force of expansion of burnt gas and air in a prime mover. These were as follows:—

a. The largest possible cylinder volume, with a minimum of containing surface.

b. Highest possible working speed.

c. Utmost expansion of the charge.

d. Greatest compression of the charge before ignition.

The patentee explains, *a*, that the largest cylinder diameter for a given volume of charge should prove the most economical, which means that single-cylinder engines are to be preferred. As to *b*, it is a question of the time of expansion and the loss of heat to the cylinder walls. Consequently, the quicker the expansion and the piston

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speed, the less heat will be lost in this way. As to *c*, it is pointed out that the pressure soon falls, because of the rapid condensation of the bulk of the combustion products. In order to prolong the expansion effect, therefore, it is desirable that the charge should be compressed before ignition to the limit set by the imminence of pre-ignition.

Although de Rochas could perceive what is necessary to the design of a successful gas engine, and especially could see through the illusory force of an explosion, and distinguish the advantage of expansive combustion of the working charge—that is, of the substitution of a push on the piston for a hammer-blow—it was not given to him to make a working machine on his own principles. Instead, his disclosure of the secrets of success proved barren, and it was only after Otto had brought out his compression-and-expansion gas engine, fifteen years later, and given his name to the cycle of the operations of the cylinder and piston, that diligent search for "paper" anticipations revealed the record of de Rochas lying on a Patent Office shelf, and established the fact that what the Frenchman knew, it had been reserved for the German to do. There are very few parallels to this instance of the why and wherefore of a mechanism being explained before the machine was made. As a rule, progress in mechanical engineering proceeds by the other path, the engine being constructed and set to work before science comes forward to define its principles and audit the extent of their realisation.

Everything is simple when one has learnt how it is done, and the famous Otto gas engine cycle is simplicity itself. The general external appearance of an engine of this type is very like that of an ordinary horizontal steam engine, except that the piston is of the "trunk" kind instead of having the usual piston rod and guides. It will be observed

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that the fly-wheel is heavier than is customary for a steam engine of the same size, or there may be two fly-wheels. There are some minor fittings attached to the cylinder which differ in the various makes of these engines, but have the common object of regulating the action, firing the charge, etc. Before treating of these details it will be desirable to briefly explain the cycle of cylinder operation, which is always the same with this type of motor. Supposing the engine to be starting, the first stroke forward draws in the charge of gas and air, which is compressed by the back stroke. This makes one complete revolution. Next, the charge is fired, and the forward stroke is that which gives the power of the engine, the backward stroke pushing out the products of combustion. The cycle then recommences *da capo*, and goes on *ad lib*. Thus, of four strokes of the piston, outward and inward, only one is a true working stroke, the others being either preparatory to or consequent upon it. This is for a single-acting cylinder, in which all the work is done on one and the same side of the piston. The power of the engine is dependent upon the number of working strokes, or impulses, within a fixed period of time. When the full cycle is being carried out, with a charge fired every other revolution, the engine is exerting its full power, but, usually, less power is required, and this reduction is effected by occasionally missing impulses. The effect of this is to increase the irregularity of the turning motion of the engine already resulting from the lapse of time between the impulses. The irregularity is reduced as much as possible in engines generating electricity by the employment of very heavy fly-wheels, whose momentum to a large extent equalizes the speed of the revolutions, and here the matter rests.

While the Otto patent was in force, various ingenious mechanical devices were adopted by other makers of gas

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engines to obtain the same cylinder results by a different way, but no sooner did this patent lapse than the Otto cycle was almost universally adopted. Yet the essential unsteadiness of the running by this cycle is admitted, and therefore gas engines having more frequent impulses at top speed have always been sought for. This result has been achieved in such motors as the Benz and the Daimler, which are the prototypes of the petrol engines of the present day; but there is an economical objection, as pointed out by Beau de Rochas, to the multiplication of cylinders in a gas engine of a given power. Consequently the single-acting, single-cylinder engine remains the standard type for stationary motors up to 100 horse-power. For larger powers, additional cylinders are taken, placed opposite one another, or side by side, or in tandem.

The Westinghouse gas engine differs from the type of those motors hitherto considered, in the manner of governing itself according to the power called for. Instead of missing impulses, this engine varies the volume of the charge taken into the cylinder, the proportion of gas to air remaining constant. The style of the engine is that of a reversed cylinder vertical steam engine of the marine type, this likeness being strengthened by the circumstance of it having more than one cylinder. The engines are made of very large powers. As all large gas engines, over 60 horse-power or thereby, are driven by blast furnace or producer gas, not by town gas, they do not come within the scope of this book, and therefore will not be further discussed.

The operation of engines of small to medium size using town gas, represents by far the greater bulk of the gas engine trade. These motors offer numerous advantages over others, of which some may be enumerated as follows:—

1. The motor is compact, space-saving, and requires none

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of the troublesome and costly provisions and arrangements inseparable from steam power.

2. There are no boilers, no stoking, no coal to store, no ashes to clear, no smoke law to beware of.

3. The gas engine lends itself to the most economical distribution of power in a factory. It is as efficient for 5 horse-power as for 50, and the consumption of gas is strictly proportional to the work done. One shed can therefore be driven as economically as ten.

4. No extra labour is required for attending to the engine. There are no making-ready expenses or stand-by losses. The power user is quite independent of all considerations outside those of his own trade.

Other advantages might be cited, but the industrial world has given so decided a vote in favour of the gas engine for all purposes to which it is suited, that the case may be taken as proven. The economy of gas power is not confined to the mere matter of running expenses, although this is where it begins. When it has been said that the consumption of town gas by an engine of good make is about 18 cubic feet per brake horse-power per hour, or under 24 cubic feet per kilowatt-hour when applied to the generation of electricity, this statement does not cover the whole ground. It neglects all considerations connected with power transmission, as distinct from its generation. For practically the first century of its existence as a piece of mechanism, engineers concerned themselves wholly with the improvement of the steam engine, and its boiler, with a view to improving the efficiency and economy of the combined plant. There was plenty of room for it. Investigation showed that the average fuel consumption of small steam power plants in Birmingham about 1880 was over 7 lbs. of coal per horse-power per hour. By the employment of high-class machinery and plant, it has been established that the fuel

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consumption of a large condensing steam engine can be brought down to an average of 2 lbs. of ordinary coal per horse-power per hour. That is the Lancashire mill standard of good working at the present day.

But this is for the engine alone, and a large one at that —say, not less than 300 horse-power. The transmission of the power throughout the mill, by means of belting or ropes, or both, costs 20 to 25 per cent. of the power of the engine. This is where the chief economy of the gas engine appears; for instead of submitting to this loss, which is consequent upon the concentration of the driving power in one engine room, most of it can be saved by placing gas engines about the floors, wherever they can do their work with least waste through shafting and belting. Moreover, it is usually possible to so plan the distribution of power that anything like a general break-down is rendered practically impossible. At Eley's ammunition factory, Edmonton, to cite only one example, the engines and counter-shafting are so arranged that any engine can be put in place of the next in series if required (the engines being of ample power for the purpose). At this large factory one oiler attends to all the engines.

The efficiency of the gas engine, judged by its conversion of the potential energy of its fuel supply into motive power, is higher than that of the steam engine; as it need be, having regard to the higher cost of the purified gaseous fuel. The brake efficiency is about 30 per cent., computed on the total heat received by the engine.[1] It was this

[1] Test of "U" type Crossley engine made 6th March, 1905, diameter of piston, 11 inches, stroke 21 inches.

Duration of test	1 hour 45 minutes.
Mean revolutions per minute	185·45.
Mean explosions per minute	91·8.
Average mean pressure of diagrams	94·92 lbs.

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consideration which inspired the oft-quoted prophecy of the late Sir Frederick Bramwell regarding the disappearance of the steam engine within fifty years. Many of these years have elapsed since the utterance of the prophecy; but its complete fulfilment seems no nearer. Both larger and smaller gas engines than Sir F. Bramwell ever saw are now in operation; but the essentials of the stationary gas engine using town gas remain as Beau de Rochas defined, and Otto realised them.

The economy of the cylinder-and-piston gas engine antagonizes the construction, or *vice versâ*. It is the property of furnaces to be hot, and the hotter they are the more economical of fuel they become. But in the gas engine the furnace (which is the cylinder) has to be cooled down from outside by a running stream of water, to prevent it from becoming too hot for working. In this way twice as much heat is lost as is accounted for in work done. The case seems irremediable. Clearly, so long as metal

Average indicated horse power	47·96 lbs.
Net weight lifted by brake rope	518·4 ,,
Effective circumference of brake rope	14·408 feet.
Average brake horse power	41·974 ,,
Mechanical efficiency	87·452 per cent.
Coal gas used per hour corrected to a temperature of 60° F., and barometer pressure of 30 in.	572·57 cubic feet.
Gas per indicated horse power	11·929 ,,
Gas per brake horse power	13·64 ,,
Average calorific value of gas as corrected to 60° F. and 30 in.	528·6 B.Th.U's.
Thermal efficiency per indicated horse power	36·9 per cent.
Thermal efficiency per brake horse power	32·27 ,,

The engine was tested under ordinary working conditions, the amount of lubrication to the cylinder and bearings being the same as usual.

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cylinders and pistons are used in the construction of these engines, the metal must be kept below the temperature at which its strength would become affected, and the lubricated sliding movement of the parts impossible. Already much has been done by the improvement of cylinder oils in the sense of retaining viscosity at high temperatures, to render possible the working of gas (and petrol) engines at much higher temperatures than were dreamt of when this class of motors was first introduced. Yet still 40 per cent. of the fuel goes to heat the jacket water. An almost equal amount is carried off by the exhaust, which also seems irrecoverable. As appears by the fourth rule of Beau de Rochas, the compounding of a gas engine or anything analogous to the working condensing, in the parallel case of a steam engine, is out of the question. The expansion is too soon over to permit of anything of the kind. Several inventors have endeavoured to utilize some of the otherwise wasted heat of the exhaust by causing it to gasify water sprayed into the cylinder while working, or to heat the air on its way to the combustion point. The risk of interruptions of the working, misfires, and so forth, outweighs any advantage that might be realised in this way.

The consumption of water in connection with the working of a gas engine is not large, as it can be used over and over again after cooling, which is an important consideration where water is scarce or dear. Several important alterations of structural details have been introduced in connection with the gas engine of late years, and constitute the specialities of different makers. The economy of the different patterns, however, does not vary noticeably in respect of gas consumption, but some of the mechanical fittings and accessories of the different engines are very clever. The compression of the charge before ignition has been worked for all it is worth. It is limited by the risk of

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self-ignition, which, indeed, is aimed at by some inventors. Compression was first adopted with the object of prolonging the expansion, but it has justified itself also by enabling poor mixtures of gas and air, and weak combustible gases, to be used in engines. The ordinary proportion of air to town gas, for complete combustion, is $5\frac{1}{2}$ to 1; but, by reason of compression, the gas engine works with 10 to 1. Not long since it was held by experts in these matters not to be economically possible to increase the size of the gas engine much beyond the powers found serviceable with town gas, on account of the great loss of heat by the jacket water. It was thought that something would have to be done to check this waste, before large gas engines could gain a footing. Yet this loss has not been checked, and gas engines of the very largest dimensions are in operation. The explanation lies in the development of compression of the charge, which has enabled these big engines to work with the poor gas saved from blast furnaces, which costs so little that it is never measured, so that the waste by the water jacket is immaterial.

Points arising in regard to the satisfactory fixing and working of an engine with town gas are—

1. Adequacy of the gas supply, in quantity and pressure.
2. Adjusting the supply to the engine so as to avoid occasioning pulsation in the neighbouring gas pipes.
3. Disposal of the exhaust inoffensively to neighbours.
4. Provision of jacket water.
5. Avoidance of vibration from the engine.
6. Placing the gas meter.

It is the business of those who fix the engine to see to these things, but the user also should be informed as to the essentials of ultimate satisfaction.

One of the most economical of the uses of a gas engine supplied with town gas is for the generation of electricity

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for private installations, either for lighting or for power, or a combination of both (Fig. 71). This arrangement is particularly favourable to the needs of banks, large commercial offices, insurance offices, retail drapers, and public buildings, where the demand for artificial light only occurs for a short period of the evening, just at what the engineers of the public supply stations call "the peak of the load."

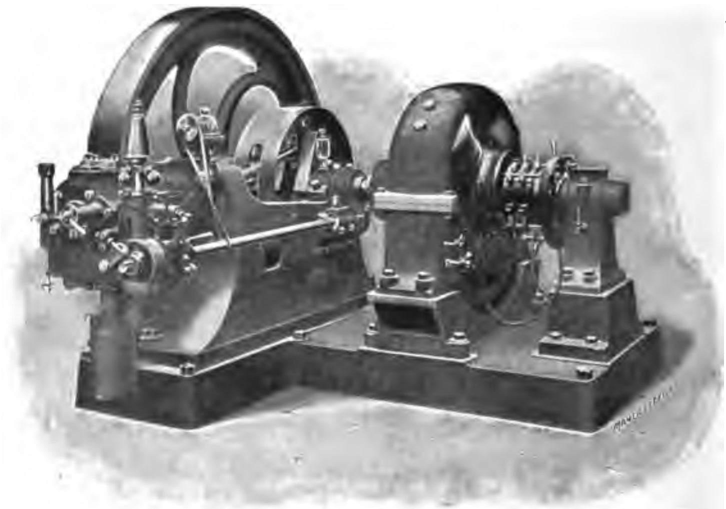

FIG. 71.—Crossley Gas Engine with Dynamo.

This is the least profitable kind of business for general electric lighting undertakings; and in most of the varied differential systems of charging for electric current in vogue it is charged for at the highest price. Indeed, this class of the business is the chief reason for the adoption of these discriminating systems, in which the object is to penalise those consumers who only take current for a short period of the 24 hours. Some municipal electricity supply under-

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takings in manufacturing towns refuse to do mill lighting, because of its unprofitable character to the public generating station, which has to keep sufficient plant and machinery ready for supplying on demand all the lamps and motors on the circuit. Therefore, in other places, where this short period lighting cannot be declined, it has to be paid for at the dearest rate that can be exacted; and even then is not a source of profit to the general undertaking.

Supposing a drapery establishment which closes at seven o'clock on five days of the week, and at mid-day on one, requires for its lighting the equivalent of 300 8-candle power lamps. All the generating and distributing plant and machinery requisite to meet this demand, which only arises from September to March, has to be provided by the general electricity supply undertaking, with 25 per cent. additional in reserve. This asset stands idle for half the year, and is only used for about one-tenth of the remainder; although interest, sinking fund, taxes, and every other standing charge go on for every hour of the whole year. Evidently it is practically impossible to frame a scale of charges for current delivered which shall be at once fair to suppliers and supplied, in the circumstances. It is, of course, the lack of any adequate means of storing electricity which accounts for this economic stricture. In the absence of any magazinage analogous to the gasholder, or the water reservoir, the reserve in the case of general electricity supply has to be in the form of capital outlay, which is a wasting reserve of most expensive character.

If the necessary generating machinery and plant is installed on the user's premises, although it has to be paid for among the general expenses of carrying on the business, like the horses and carts, all the costs of distribution, administration, and reserve are saved. The gas company

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keep the stand-by power in their gas holders, which is a saving form of reserve. Therefore, the cost of electricity by an isolated plant of this description is not more than the works cost of a public central station, that is, about one-third or one-half of the average distributed price per unit.

Nor is this the only advantage of a private electric lighting service. It is admitted that steadiness of the voltage is a ruling consideration in determining the durability of lamps. Many public supply systems are very hard upon the lamps, by reason of over-pressure and irregular voltage. When a lamp is marked for a certain voltage, that is the voltage at which it should be run; but this is a "counsel of perfection" in regard to a public supply. The obligation to keep the voltage in the distribution network within the smallest possible extremes of variation, as Mr. James Swinburne has pointed out, imposes a heavy burden on the undertaking, which would be commensurately lightened if a kind of lamp could be devised that would be more tolerant of oscillations of electrical pressure than the usual carbon filament incandescent lamp.

According to the experiments of Sir William Preece and others, the effect of excessive voltage on the carbon incandescent lamp is as follows:—

An excess of 1 per cent. of the voltage diminishes the life of the lamps 16 per cent.

An excess of 4 per cent. of the voltage halves the life of the lamps.

An excess of 7 per cent. of the voltage reduces the life of lamps to one-third.

An excess of 10 per cent. of the voltage reduces the life of the lamps to one-fifth.

After the first few hours of over-pressure the light of the lamps falls off considerably, although the same quantity of current is used. If, on the other hand, the voltage falls

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below the standard marked on the lamps, their illuminating power is very rapidly decreased; and this is what is liable to happen during the hours of greatest demand, and very often characterises the quality of lighting obtainable on occasions of sudden, unexpected demand, as during fogs. With a private installation run by an engine using town gas, there need not be any unreadiness or irregularity. With a turn of the wheel the engine starts, and the full amount of the lighting in circuit can be had for five minutes, or for any length of time, for the price of the quantity of gas consumed.

Another advantage which the owner of a private plant of this description enjoys, is that of being able to suit himself both in the voltage at which he runs the system, and consequently in the kind of lamps he will use. This is a matter that has come into great prominence recently, in connection with the improvement of electric lamps suitable for indoor use. As is well known, the question of the voltage at which a public electricity supply shall be given is one that the administrations of these undertakings settle at their own discretion, which in the first place is naturally self-regarding. Originally these supplies were at no more than 50 volts, which permits of the running of either arc or incandescent lamps at will. Indeed, commercial electric lighting began with arc lamps, about the year 1878, and therefore the service of current would naturally be adjusted to the requirements of such lamps, which is 50 volts. The earliest incandescent lamps, therefore, were manufactured to this standard voltage. It was soon discovered, however, that if anything like a general public distribution of electricity for lighting was to be undertaken on business lines, a higher voltage in the network must be arranged for in order to enlarge the area capable of being served from one generating station, and to

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economize copper in the mains. It was not thought possible at first to command a greater radius than half a mile from the central station, which explains the situation of the stations in such localities as St. James's, and Sardinia Street, Lincoln's Inn.

The manufacturers of incandescent electric lamps saw no objection to the raising of the voltage of currents to 80 or 100 volts, at which a vast bulk of public and private electric lighting was accomplished. Ship lighting is still done at these voltages, which are on all accounts the most suitable for incandescent lamps of every description. The exigencies of central station working, however, expressing themselves in the call for the service of an ever-extending district from one station, and the necessity for doing so at the cost of the least possible weight of copper in the street mains, irresistibly forced these undertakings to increase their voltage to the legal maximum, which is 500 volts across the wires. This change was ill-regarded by the incandescent lamp makers, who had difficulty in manufacturing small-sized lamps to endure the higher pressures, and also in keeping the current consumption of even the larger sized lamps to the standard that had been established for 100-volt lamps. The consumers were ignorant and helpless in the matter, but were assured that the change would benefit them in the long run, by the reduction of the price of current to be expected from the general saving of expense that would ensue upon the alteration.

Meanwhile, the "bird in the hand" was sacrificed to this problematical prospect, which was a product of the central station system of electricity supply, and would no more have attracted the user of privately-made current than it has done the ship-lighting branch of the electric lighting industry. As a matter of fact, not only has the manufacture of carbon filament incandescent electric lamps fallen

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short of the ability to produce as good and economical results from the high voltage currents now in vogue for town supplies; but hitherto these high voltages have also proved an insuperable bar to the free employment of the more efficient kinds of incandescent electric lamps that have been recently put upon the market. Without going further into the economics of this question of the balancing of station savings *versus* consumers' expenses, it may be pointed out that the user of electric light whose wants are large enough to warrant his putting down a private installation for gas power is independent of all such considerations. He can adopt whatever voltage he is advised as being safest and most convenient for any kind of lamp. He is able to run his carbon filament lamps, of anything from 5 candle power upwards, for an average current consumption of 3½ volts per candle; while the average for larger lamps on the high voltage circuit is 6 volts[1] per candle power. And he can avail himself of the full benefit derivable from tantalum lamps, or any other promising novelty. Of course, it is a simple matter to generate in the same way electric power of small to medium amount for the driving of sewing machines, ventilators, fans, lifts, presses, etc.

Great progress has been made of late years in the driving of isolated gas power plants, on manufacturing premises, by special low-grade gas made on the spot in "producers." This department of power generation is beyond the scope of this book, and is only mentioned here in order to remind possible gas engine users that it does not compete with the

[1] This is a quite moderate figure, although it is half as much again as the consumption per candle power (4 watts) which used to be reckoned as standard for the incandescent carbon filament lamps of years ago. Mr. Geo. Wilkinson, Corporation Electrical Engineer, of Leeds, has testified to instances of consumers wasting as much as 9·14 watts per candle power, in the case of Continental-made lamps.

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application of town gas to this purpose, not being suitable for strictly town premises.

The cost of generating a unit of electricity by town gas will lie between $\frac{1}{2}d.$ and $\frac{3}{4}d.$ for actual working expenses, or between $1\frac{1}{2}d.$ and $2\frac{1}{2}d.$ per unit inclusive of everything, *i.e.*, interest on capital, depreciation, repairs, water, oil and attendance, in addition to the cost of the gas consumed. The cost is largely dependent upon the use made of the installation in proportion to its total capacity of output; but the standing charges are small, as it is not always necessary to pay for engineman's labour. The size of power plant required is arrived at by allowing 20 8-candle-power lamps, or their equivalent, to 1 horse-power. The smallest set for the purpose that can be confidently recommended is that rated in the makers' lists at about $5\frac{1}{2}$ indicated horse-power, or $4\frac{1}{2}$ horse-power effective, which will work in a ground-floor space of about 8 feet by 4 feet. Examples of such installations abound in London and the chief towns of the United Kingdom, supplying banks, theatres, places of entertainment, drapery and general retail stores, wharves, boot and shoe manufactories, and town houses. In short, the range of suitability of this method of providing electric light and power for town premises is more extensive than would be suspected by anyone who has not given thought to the subject.

The following estimate refers to a scheme for lighting premises in the North of London (1907):—

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Approximate Cost of Gas-Driven Installation for Generation of Electric Light, and Saving effected as Compared with taking Current from the Mains.

							£	s.	d.
Three gas engines with generators combined, each capable of an output of 60 kilowatts, delivered and fixed on foundations provided by consumers							3,312	0	0
Interest and depreciation on above sum at 10 per cent.				£331	0	0			
Renewals and oil at, say, 3 per cent.				100	0	0			
Cost of gas reckoning on a consumption of 30 cubic feet per unit, and on an output of 150,000 units per annum at 2s. 11d. per 1,000 cubic feet	£656	0	0						
Less discount of 25 per cent. as per company's scale for gas for power purposes	164	0	0						
				492	0	0			
Labour, say mechanic and mate				182	3	9			
Annual expenses							1,105	3	9

	£	s.	d.
Taking 150,000 units from the mains, on a lighting scale, at 4d. per unit, equals	2,500	0	0
Total cost as per above figures, to generate same number of units by gas-driven installation	1,105	3	9
Representing an annual saving of	1,304	16	3

It will be noted that the total cost per unit generated by gas is only 1·76*d*. per unit. The price of the unit quoted here (4*d*.), supplied from the public mains, was correct at the time; but since then the price has been much reduced, although the former figure more nearly represents the proper commercial rate of charge, to carry a small profit.

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CHAPTER XI.

THE LEGAL RELATIONS OF GAS SUPPLIERS, CONSUMERS, AND THE PUBLIC.

Origin and development of the law of public gas supply in the United Kingdom—Its necessity—Private Gas Acts and Provisional Orders—No monopoly—The principles of the Gasworks Clauses Act, 1847—The wisdom of Parliament—Foreign legislation relating to gas supply—Results of the discontinuance of competition in the British gas industry—The districting of the metropolis—The amalgamation of gas companies—The creation of the board of gas referees—Passing of the Sale of Gas Act—Objects of the Gasworks Clauses Act, 1871—Adoption of the sliding scale of selling price and dividends in 1875—Enactment of the auction clauses in regard to the issue of new and additional gas capital in 1876—Profit-sharing and co-partnership embarked upon by the South Metropolitan Gas Company—Municipal gas undertakings and their "profits"—The limitations of gas companies' statutory powers—Supply of gas compulsory—The law of gas meter registration—Collection of accounts, etc.—The law of nuisance; and gas companies' responsibility for "negligence."

The law of gas supply in the United Kingdom has grown by successive grafts upon the Common Law of the realm, together with assimilation of portions of the statute laws relating to the public health, to joint-stock companies, local government, and other legislation of a general character, with in most localities a superstructure of private Acts of Parliament. Every nation has its own peculiar way of localising gas undertakings, which, being fastened to the soil, and compelled by the nature of their operations to trespass upon the public roads, require authority for doing the latter and possession in respect of the former. As the

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gas industry originated in England, it was the British Parliament which in the early years of last century was called upon to make room for the new claimant upon the rights accorded to citizens under the British Constitution. A Bill was promoted to empower the King in Council to grant a Charter to the first gas company, and at the second attempt an Act for this purpose was obtained. The Chartered Gas Company, as it came to be called, duly received the Royal Sanction to do without let or hindrance all such things as might be necessary or desirable for the proper conduct of the enterprise. The first necessity in this respect is power to break up the public roads for the purpose of laying gas pipes underneath the surface, and to repeat the operation as and whenever required for repairing, enlarging, or making connections to the same. This power is a gas company's *sine quâ non.* It does not reside in any private person, outside a private Act of Parliament conferring it upon grounds of general expediency; for the system of Royal Charters is not a suitable means of dealing with such a matter, and the experiment was never repeated.

The act of breaking up a public highway is a nuisance which the Courts will restrain without requiring proof of specific damage; therefore it is a rash proceeding for a gas company to attempt, unless protected by a private Act, or (which amounts to the same thing) by a Board of Trade Order. Yet in rural districts this sanction is often foregone by agreement between the undertakers of the supply and the local highway authority, with a view to saving the cost of an Act. Since the system of Provisional Orders has existed, however, this condition of gas supply on sufferance should not be continued, as the cost of obtaining statutory protection in this form is trifling. It has happened that the company and the local authority have quarrelled, with the result that the company have been debarred from touching a main

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in the ground until they could obtain relief from Parliament. The value of statutory protection is recognised in the price paid for a gas undertaking upon its being taken over by a public body.

It is to be pointed out here that the popular notion of a statutory gas company having a "monopoly" in their district has no foundation in law. All that is granted to a British gas company of the nature of a privilege, is the right to acquire land compulsorily, and to break up the roads for laying mains in the subsoil, which is common property. Any inhabitant can make gas for his own use, if he chooses to run the risk of creating a nuisance to the injury of his neighbours, and can sell the same to residents on his own lands, or adjoining, provided that he can supply the commodity without breaking up a public road. Examples of this proceeding are numerous in respect of collieries, ironworks, mills, etc., situated in statutory gas supply districts.

In return for the grant of power to break up the roads (for which, by the way, it is very exceptional that any rent or tax has to be paid to the highway authority, as the subsoil is public property for the common use of all having need of the accommodation) gas companies are laid under numerous stringent obligations conceived in the best spirit of British lawmaking. They are forbidden to make any distinction between consumers of the same class or order on their books; they are under compulsion to supply all applicants; and they are not allowed to make a penny of profit in excess of the amount certified to be sufficient to pay the statutory dividends, after all proper charges on capital and on account of reserve, insurance, and upkeep have been duly provided for. The amount of capital employed in the undertaking is limited by the private Act; so that the company must resort to Parliament at reasonable intervals for

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permission to raise any additional sum required to meet a growing business. It is quite safe to say that no other nation has so justly and wisely legislated for its gas supply, so fairly adjusted the claims of capital to reasonable remuneration, and so effectively secured the even treatment of the public and the progressive cheapening of the supply. These are large claims, but they are admitted by those who are conversant with the practice of different countries, and their justice is, indeed, incontestable.

Where the wisdom of Parliament was mainly displayed in this special legislation (apart from the recognition of private enterprise, which was equally extended to railways and water supply) is in the two cardinal points of only allowing a limited tether to gas companies in the all-important matter of capital (with publicity), whereby they are bound to return to Parliament from time to time, and can then be called to account for all their proceedings; and in regulating the amount of the dividend. Original capital, in view of the hazardous character of new enterprises of the kind, and the certainty that profits would be small at first, was allowed to take a 10 per cent. maximum dividend, and additional capital, raised after the undertaking had become successful, was allowed 7 per cent., with permission to make up back dividends when circumstances permitted. Not more than one-fourth in amount of the share capital was allowed to be borrowed and treated as loan capital. The usual provisions to this effect, and concerning other matters common to gas companies, were first collected in the consolidation Act known as the Gasworks Clauses Act, 1847; which was optional for undertakings subsequently incorporated. At that period competition in gas supply was common in the best town districts; and the sale of gas either by measure, or for a rent or rate, was matter for agreement. Consequently, nothing could be defined in

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respect to the price of gas, which was left at the discretion of the parties to the bargain; but the Act was very explicit as to the amount of the divisible profits, which were in no case to exceed 10 per cent. per annum on the paid-up capital of the undertaking, with what might be requisite to make up back dividends to this figure. The profits might also be drawn upon to form a reserve fund of 10 per cent. on the nominal capital of the company; but after that the charges for gas for the ensuing year had to be adjusted to what might be established before a competent and impartial tribunal to be sufficient to ensure the same amount of profit.

The profound wisdom of this provision may not strike the reader at first sight, but it is really the source of the whole legislative and financial influences that have combined to cause the gas supply of the United Kingdom to be the cheapest in the world. The "old parliamentary hands" of the first third of last century hit upon a principle which eluded the scientific Frenchmen, the other Continental Governments, and the go-as-you-please Americans, who all aimed at cheap town gas, and missed it. This conclusion is borne in upon anyone who examines the expedients that commended themselves to these foreign legislators for gas supply, respectively. Although a Frenchman, Lebon, was one of the earliest inventors of "gas," in the technical sense, it was not until after the industry of gas supply from public works had grown up in England that it became acclimatised in Paris, and engaged the attention of the French Government. In due course a "Treaty" was framed for regulating the gas supply of Paris, after consultation with the contemporary lights of French science. This was in 1856, and was made for fifty years. It never occurred to the logical French minds which settled the clauses of this Treaty referring to the price of gas, that any

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other than physical causes could affect the cost of manufacture; and accordingly it was enacted that in the event of any discoveries or inventions being introduced in the gas industry generally, during the existence of the Treaty, which might have the effect of materially reducing manufacturing expenses, the Paris Gas Company should adopt such improvements and give the public the benefit thereof. In order to render this provision effective, a technical commission to investigate the facts might be appointed at intervals of five years on the initiative of the Government of the day. Not one halfpenny of reduction of the price of gas has followed upon this enactment, although several costly technical commissions have held prolonged and exhaustive inquiries into the circumstances of the Paris Gas Company, whose charge for gas remained fixed at the figure of 1856; notwithstanding the fact that technically the gasworks and methods of the company were quite abreast of those of the London gas companies, who within the same period of time had reduced their charges by one-half. The explanation of this difference of the net result is to be found in the different incidence of the regulating machinery. In the English case, the Legislature ignored every other consideration besides that of the profits of the undertaking; whereas the French administrators were led astray by their regard for technical details which do not govern the main issue. It is magnitude of the turnover, volume of output, the fullest employment of capital and staff, which rule the cost of production far more than any saving by a manufacturing process assignable to some particular invention. Therefore, the English law goes straight to the point and the root of the matter, while the French attempt at precise scientific regulation failed lamentably to secure its object.

Over the rest of France, and generally throughout the European continent, and farther afield, the concession

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system has chiefly governed the gas supply. The essence of this system is limitation of the tenure of the privilege, which necessitates high charges. Incidentally, also, it profoundly divides the interests of the gas company and the community, which should be united as closely as possible, with the inevitable result that capital, directed by intelligent skill, gets the better of public interest not directed by any skill at all. In the United States, uninstructed credulity on the part of the public in the merit of the principle of competition, in gas supply as in retail trading, has almost everywhere led the way to an oppressive financial monopoly of the business on the much-abused "Trust" system. The American communities could not or would not perceive that competition between similar public supply undertakings which are tied to the same soil is wasteful and absurd. The lesson was learned in England half a century ago. Town life can no more tolerate or support two gas companies competing in supplying the same article, than it could allow two rival tramway companies in the same street. In the United States, however, even the latter anomaly has appeared; and there are few towns which have not suffered from the infliction of several contemporaneous gas companies, which must eventually either divide the district, or consolidate. In either case the public has to pay in perpetuity for a brief period of administrative aberration; and cheap gas is rendered for ever impossible by the dead load of wasted capital.

By 1860 the delusion of competitive gas supply was definitely exposed in England, and the statutory gas companies doing business in London agreed among themselves to a Districting Bill, "in order to economise capital and avoid the too frequent opening of the public streets," which became an Act that same year. These companies were thirteen in number; and the opportunity was taken of

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introducing uniformity into the regulations subsisting between the companies and the public, including the enforcement of the sale of gas to private consumers by meter, for which provision had been made by the general Sale of Gas Act of the previous year. By this Act, also, the companies bound themselves to keep all distributing pipes fully charged at all times with gas. Eight years later, many of the companies having grown tired of contemplating one another across innumerable streets, an Act was passed by mutual consent enabling such of the undertakings as were so disposed to amalgamate, with a view to saving working expenses, which was accomplished during the following years, leaving only three independent gas companies actually carrying on business in the metropolitan area, namely, The Gas Light and Coke Company in the City, and the north of the Thames generally (with an outlier in Battersea); the South Metropolitan Company in the region indicated by its title; and the Commercial Company, which lies within a ring-fence around Stepney as a centre. Financial as well as geographical and administrative considerations conduced to the survival of these three London gas companies, inasmuch as with them proof failed as to the probability of further economy being effected by their absorption in one another.

By the same Act a very important and far-reaching improvement was effected, in the constitution of a Board of Gas Referees, who are eminent men of science, and are charged with the duty of prescribing the measures to be taken for testing the quality and purity of the gas supply. The practice of the Referees has in course of time come to be regarded as authoritative on these matters in other parts of the kingdom.

The next important landmark in the gas legislation of the United Kingdom was the passing of the second Gasworks Clauses Act, 1871. This law was made of compulsory

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application to all statutory gas companies going to Parliament later; and as it also incorporated all consistent provisions of the Act of 1847, the gas undertakings of the country were soon, with few exceptions, brought under these combined statutes. This is the enactment which laid the obligation of compulsory supply upon the undertakers, by way of corollary to the recognition of the practical discontinuance of competition. It also made general the requirement to consume gas by meter. It ordered the testing of gas for illuminating power and purity, and dealt with public lighting. The form of keeping and publishing gas companies' accounts was also prescribed; and facilities were granted for the recovery of money due to the undertakers from the consumers whom they were compelled to admit to their books.

The latest general alteration of the law of gas supply throughout the United Kingdom, including the Metropolis, was not effected by any public Act, but came tentatively first as a clause in the Commercial Gas Company's Act, 1875. There had been during many years previous to this epoch acute dissatisfaction on the part of the Corporation of the City of London, and later on the part of the Metropolitan Board of Works, and other metropolitan local authorities, with the results of the operation of the law and practice of gas supply in London. It was felt by the body of citizens who did not happen to be shareholders that gas ought to be cheaper, if the spirit of the Act of 1847 were properly regarded; and to the prevalence of this discontent, to which was joined a certain jealousy of the secure investments of the proprietors of the older companies, was due the launching of the last great competitive gas undertaking within the metropolitan area, the Great Central Gas Company, whose creation was the "sensation" of the "fifties." But this company shared out with the

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others in 1860, and the popular discontent remained unappeased.

After several experiments in other directions which came to nothing, the Commercial Gas Company, who happened to be in Parliament in 1875 for additional capital powers, accepted the proposal for a sliding scale of selling price and dividend, by which the old institution of a maximum price, intended to secure the earning of the maximum dividends, was abrogated in favour of a standard, or initial price, at which the Company were allowed to divide the maximum dividends of 10 and 7 per cent. If and whensoever the revenues of the undertaking permitted the reduction of the selling price of gas below the standard price, which in this instance was 3*s.* 9*d.* per 1,000 cubic feet, then for every penny per 1,000 cubic feet of such reduction previously made, the dividend for the period might be increased by $\frac{1}{4}$ per cent. per annum. Similarly, any increase of the selling price was to be attended by an equal reduction of dividend. The industrial world has since become familiar with the principle of sliding scales in various connections; but at the era now in question it was a novel experiment, and regarded with much misgiving. The following year the two other metropolitan gas companies followed suit, with the added obligation to sell all further capital issues to the highest bidder, at auction or by tender. This completely throws open the proprietary of gas undertakings. In later years, many gas undertakings, led by the South Metropolitan Company, have made special provision for the admission of shareholders drawn from the general body of consumers, and particularly from their own workpeople. It scarcely falls within the scope of this book to describe the profit-sharing and workman-director dispositions of the South Metropolitan Gas Company; but these are among the most notable sociological phenomena of the age.

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By virtue of the sliding scale of selling price and dividend, the intention of the Act of 1847 has been revivified, and caused to prevail against the inertness to which the statutory protection of the maximum dividends by a rampart of a trustworthy maximum selling price was conducive. It also substituted the promptings of self-interest for the external compulsion along the path to cheapened gas which might have been, but seldom was, brought to bear under the Act of 1847, with its machinery of inspection of accounts and proceedings at Quarter Sessions. However this may be, the development of the statutory industry during the period that has followed its opening up by the legislation inaugurated in 1875-6 has been very remarkable. In popular belief this expansion is attributed to the pressure of electric light competition; but while making all due allowance for this contemporary influence, it is more than probable that the transfusion of new blood, and a fresh inducement to effort which accrued to the gas industry in consequence of the legislative movement now in question, should receive most of the credit for the change.

It is a long time since the supply of gas was undertaken by the first municipal bodies to give their attention to the subject. Certain municipal corporations in the manufacturing parts of Lancashire (Manchester and Stockport being the leading examples) have always possessed their own gasworks; but it is rather a disillusionment to anyone who might be disposed to regard this as a pattern condition of affairs that it has by no means proved an ideal arrangement for all the interests concerned. Most municipal gas undertakings have been acquired from the companies which founded them; and in very many cases the price of gas is unduly kept up in order that a forced subsidy may be handed over to the imaginary aid of the rate
aid is in most instances illusory, because it

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with a reduced assessment, and has to bear a wholly gratuitous income tax, being ranked as "profit." It is easy to make a profit of this kind, when the vendors can fix their own price for the commodity. The London and other company-owned gas undertakings which are rated up to the last penny, pay more proportionately in rates than many large municipalised gas undertakings contribute by the name of profits. Apart from their financial relations, municipal gas undertakings are carried on under the same laws that govern gas companies.

The law of gas supply is not in opposition to the common law, or the statute law as enacted in such general Acts of Parliament as the Companies Acts, and the legislation relating to public health and local government. It is only special to gas undertakings in respect to their corporate existence and operations; for it is a principle of the law of such corporations that they cannot go outside the four corners of their Acts of incorporation. That is to say, no statutory undertaking can do anything which there is no sanction for in the terms of the incorporating statute. It has no existence outside these. Consequently, English gas companies were as a rule powerless to hire out gas apparatus for the use of consumers, to allow discounts for different classes of consumption, to own railway trucks or collier ships, until they included all such ancillary proceedings in their later Acts. It was for a long time considered that the concern of gas companies in the gas they distributed ended at the consumer's meter. This is so in regard to the responsibility for fires and explosions and other consequences of the use or misuse of the supply by the consumer after it has passed into his possession. But in some respects the undertakers are held responsible for what is done with their gas after it has passed the meter. The law is still nebulous; but generally

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speaking gas undertakings have not shrunk from whatever may be the risk of supplying consumers' fittings, and making themselves responsible for the sound and satisfactory installation of gas burners of all descriptions.

Usually, would-be consumers are required to enter into a written contract with the gas company to take a supply of gas and pay for it at stated periods, at the ruling price. This condition precedent to a supply is, however, often foregone; and the relations between gas companies and their customers are being more and more assimilated to those existing in ordinary commerce. At the same time, it must be remembered that statutory suppliers of gas have not the ordinary trader's choice of giving credit. By the Gasworks Clauses Act, 1871, the undertakers are bound to supply private householders with gas, on demand, if the premises are situated within 25 yards of the main, and they must lay 30 feet of service pipe gratis. They are allowed in doubtful cases to require a guarantee of payment, or to demand a deposit (for which they must allow interest), or in particular instances to insist on payment in advance.

Prepayment meters are usually provided only for small property, although in some neighbourhoods other special arrangements are made for enabling consumers (such as lodging-house keepers) whose wants are irregular to help themselves to just so much gas as they are willing to pay for in advance. Inquiries on this subject should be addressed to the local gas offices, by those whom it may concern. The penny-in-the-slot meter is emphatically the poor man's and woman's friend. It goes with a full equipment of internal fittings, lighting burners, a cooking stove, and perhaps a small gas fire or two. The class of houses and tenements in the occupation of the people whom the slot-meter is intended to serve are not usually fitted up for gas, which circumstance was for some time regarded as an

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insuperable obstacle to their having a supply. The landlord would not put in the pipes, and the tenants could not afford to do so. Even where the gas was laid on, the usual quarterly collection of the rental did not agree with the circumstances of the occupants of weekly property. The gas companies, however, took upon themselves the risk of putting in the necessary pipes and fittings, and recouping themselves by a surcharge on the price of gas, which is usually limited by the Act to 10*d.* per 1,000 cubic feet. A form of agreement is generally signed by the consumer, by which he engages to make good any deficiency in the sum of money collected from the cash-box of the meter from the amount shown to be due by the registration of the ordinary index; the company, of course, refunding any excess.

The reason for the foregoing arrangement is that the law of this means of obtaining gas is not quite clear. The slot-meter is regarded by some magistrates as the agent of the supplier, and insertion of the coin as equivalent to payment over the counter. The objection to this view is that the meter in fact remains in the custody of the consumer, who, unless held responsible for the integrity of the cash-box, might be a party to systematic robbery of the company. The circumstance of the meter being accessible for the purpose of inserting the coin facilitates fraudulent experiments upon its internal economy, from which the proprietors cannot protect themselves. Nor is the branch of business in question so lucrative, that there is any material inducement to a gas company to put themselves to much trouble and expense for its sake. In point of fact, unless the slot-meter consumer makes pretty regular use of the cooker, and has a little gas fire for the winter, his account barely pays the expenses, and the inclusion of slot-meter customers in the statistics of gas supply makes a notable reduction of the average profit per head, or per service.

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Still, in the mass the slot-meter consumption undoubtedly helps the undertaking by increasing the total demand, and bringing into fuller use mains laid in the poorer class districts originally for public lighting only. There is no legal obligation on the companies to supply gas in this way, and they can therefore in a modified sense choose their customers in this class. There is not much friction between slot-meter consumers and the companies. The former appreciate the convenience too highly to imperil its continuance, and the confidence of some of these poor people in the meter is such that they use it as a money box for small savings until the collector comes round!

No consumer's gas meter ranks in law as an absolute arbiter of the quantity of gas consumed. It is no more than a *primâ facie* indication of this quantity, which can be contested before the Court by either party, for adequate reasons. The accuracy of the registration of gas passing through a meter, as already explained, is guaranteed as far as possible by the testing and stamping of meters under the Sale of Gas Act, 1859; but it is obviously impossible to make sure that a wheel shall not go wrong in the indicating train, and it would be out of harmony with the spirit of English justice to bind the legal responsibility of people by the mechanical counting of an instrument. Any consumer who may suspect the correctness of his gas meter can have it tested, either *in situ* or after removal, and if it is found to be incorrect no charge will be made, and the account will also be adjusted as from the last meter-taking. In general, the company watches the amounts of private accounts pretty narrowly, and consumers should do the same, in order to trace any irregularity to its cause.

Gas accounts are usually, in the United Kingdom, collected quarterly. A rent is generally charged for the meter, and there is no obligation on the consumer to take any

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gas at all. That is to say, he can have a gas meter on the premises as a stand-by in the event of the failure of electric light, or a private gas-power plant, without being bound to use it. In some districts there is no charge for the meter. Persons entering upon the occupancy of premises are not liable for the gas arrears of the out-going tenant, unless this has been specifically arranged for. When leaving, a written notice of discontinuance should be sent to the gas office, without which liability to pay for any gas consumed may extend to the next usual period for taking the index registration. If the charges are left in arrear, the gas may be cut off without notice, and the costs of cutting off and restoring the supply are chargeable in addition to the amount in arrear. Gas accounts are recoverable by summons before justices, and enforceable by distress, not by County Court proceedings. No complaint as to the quality of the gas, or as to the supply in any respect, can be raised as a bar to recovery. Sums due for hire of fittings may be included in the summons. Such chattels, the property of the gas company, are not subject to distraint for rent, provided that they bear upon the front a label declaring the ownership.

The public lighting of streets by gas is usually subject to contract, renewable at stated periods. By the Act of 1871 the price for this service is to be settled by arbitration, failing agreement, but the private Act generally makes provision for this charge, which is commonly at the lowest rate allowed any private consumer for lighting. It is very general for special discounts to be given for large private consumption, and sometimes for gas consumed for particular uses and separately measured.

Agitations among the public in regard to the price of gas, once fairly common, are never heard of now that the sliding scale has united the interests of suppliers and

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consumers in bringing down the selling price to the lowest figure consistent with sound finance; while the admission of all new and additional capital by open sale has removed everything like envy of a privileged proprietary. Recently, the stability of gas property has led to a large increase of the proportion of loan to the share capital of the companies, and this process is only restricted by the consideration that the amount of dividend ought to remain the largest capital charge upon the profits, inasmuch as it alone is subject to increase or decrease. The sums paid as premiums on new issues are applied to the purposes of capital, but do not earn anything. During the past ten years, many of the old original capital stocks of companies bearing 10 per cent. dividends have been converted to stock of a denomination more nearly corresponding to the actual return upon the investment. Thus, all the largest gas companies now have only one denomination of stock, usually 4 or 5 per cent., and one rate of debenture interest. The amount of money required to pay the converted dividend and interest remains the same, whilst there are certain economies and conveniences attaching to the new arrangement, which are recognised by Parliament as furnishing ample justification for the financial operation of stock-splitting.

Gas suppliers are amenable, like every other subject, to the common law of responsibility for negligence. This obligation has extremely wide limits, which are occasionally contested before the Courts. The same remark applies to the liability of gas manufacturers for nuisance, which has given rise to heavy litigation. Broadly speaking, the responsibility of a subject for his actions extends until it is stopped by the responsibility of another. The difficulty here is to define the limitation. A gas company has a statutory right to do all such things as may be necessary for the proper and economical conduct of its business. It

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cannot be sued for what cannot be helped, such as the emission of smoke and steam from the works, the obstruction caused by breaking up the roads for main laying, the interference with light and air by the rising of gasholders, and a hundred similar consequences of its ordinary operations. These, however, must fall within the scope of its necessary proceedings, or be covered by the terms of the special Act. So narrowly are the latter provisions interpreted that the laying of a tar main in the public roads is not lawful, unless power to do so has been expressly acquired, although the advantage to the public of piping tar instead of carting it from the gas works to the wharf or railway goods-siding is obvious.

Moreover, in carrying out such trade processes as are unavoidably offensive, a gas company is bound to exercise the utmost care, and to use the best known means of avoiding the causing of a nuisance. It is eminently desirable that gas companies should be held very strictly to account in this respect. Lax administration of the law merely tends, usually, to spare careless and indifferent works management, for there is no good reason why a gasworks should give any substantial cause of offence to the neighbourhood. Gasworks of all but the very smallest size, in which steam machinery is employed, are classed as factories, and those in which the ammoniacal liquor is treated for the manufacture of sulphate of ammonia must be registered under the Alkali, etc., Works Act, and come under regular inspection by the Home Office.

Gas companies are required by the Courts to exercise a high degree of watchfulness over all their distributing plant and apparatus whereby fire or explosion might arise to injure life and property. As it has been somewhat whimsically expressed, gas is like a wild animal, whose propensities for doing mischief are known, and who must

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be held in safe keeping accordingly. No man is bound to keep a wild animal upon his premises; but if for any reason of profit or pleasure of his own he chooses to do so, he must take all the natural consequences. Therefore, when a gas main that had been laid for some years in a private, undedicated road became deprived of support through the removal of the subsoil by a builder, so that the main broke and an explosion of gas followed, the gas company had to pay damages; it being held that it was their business to look after their own property. On the other hand, gas companies are no more than other persons required to foresee the future, nor do impossibilities. If a gas main was properly laid in the ground twenty years ago, before heavy steam rollers, motor trains, and other forms of modern traffic, putting an extra weight and pressure upon the roads, had appeared, the company cannot be required to bear the expense of relaying it, nor be held responsible for what may happen in consequence of such unforeseen uses of the road surface. Highway authorities are primarily concerned with the surface of the roads only. Their responsibility refers to this, and is centred in it. They have nothing to do with the subsoil except consequentially. Sanitary authorities use the subsoil of the roads for their sewers and drains, on the same footing as gas and water companies for mains; the Postmaster-General for telegraphic wires and pneumatic despatch tubes; and tramways for their own purposes. Hence among so many claimants to this accommodation the clash of interests is sometimes perplexing enough; injuries have wonderful ramifications, and it is by no means easy to fix responsibility for mishaps upon the right shoulders.

The fouling of watercourses and the pollution of wells by drainage from the works have often caused trouble between gas companies and public authorities or neigh-

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bouring landed proprietors. Gasworks are absolutely forbidden under heavy penalties to discharge washings or other waste liquids into any stream, however foul. The fact of a stream being no better than a common sewer for the reception of manufacturing discharges and ordinary town sewage does not warrant a gasworks in fouling it more. This legislation dates back to the period when gas manufacturers experienced great difficulty in getting rid of their ammoniacal liquor, the process of converting it into sulphate of ammonia not then being known. When this process was first introduced, other complaints arose, it being found that the discharge of sulphuretted hydrogen gas from the liquor saturators was a nuisance, which, curiously enough, was more noticeable at a distance from the works than near the spot. The reason for this phenomenon was that the heated gaseous emanation, which was carried away from the works by the wind, fell down as it grew cold and was betrayed by its odour. The processes now in use for the same purpose do not give rise to any such nuisance; but there is a certain quantity of fluid waste to be disposed of which can be turned into the sewers without detriment to any system of sewage treatment in operation.

Income tax has to be paid on gas company dividends, by way of deduction from the amount of declared and divided profits. It is not therefore lawful for a gas company to pay dividends free of income tax. Gas undertakings are rated for the relief of the poor and local sanitary charges upon the same principle that governs other hereditaments which are contributable to local rates; that is, the basis of valuation for assessment is the amount of rent by the year that a tenant might be expected to be willing to pay for the enjoyment of the property. Inasmuch as gasworks never are, in fact, let to a yearly tenant, it is necessary to ascertain the hypothetical rent that every separate undertaking would

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bring in to the landlord. This valuation is a special proceeding conducted according to precedents and rules which are understood only by experts. The broad result is, that where gas property is not favoured by an official municipal valuer, as being municipal property, the rates levied may amount to as much as 10 per cent. of the price of gas. The total burden of rates and taxes on the gas companies supplying the administrative county of London amounted in round figures, for the year 1906, to £440,000.

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